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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See Advertisement, April 7, page 47.

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See Full Page Advt. page 48, April 7.

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GEORGE WILSON HEATH and GEORGE ANDREW HEATH, both of Observatory Works, Crayford, in the County of Kent, Scientific Instrument Makers, seek leave to amend the Specification of Letters Patent No. 23518, of 1913, granted to them for "Improvements in Thermometers."

Particulars of the proposed Amendment were set forth in the *Illustrated Official Journal (Patents)*, issued on the 5th April, 1916.

Any person, or persons, may give notice of Opposition to the Amendment by leaving Patents Form No. 18, at the Patent Office, 25, Southampton Buildings, London, W.C., within one calendar month from the date of the said Journal. D 999

University of Liverpool.

SESSION 1915-1916.

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By Order,
ROBERT CLAY,
Clerk to the Guardians.

Clerk's Office,
218, Kingsland Road, N.
11th April, 1916. E 39

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THE RUNNING OF BOILER PLANTS AND NATIONAL ECONOMY.

By D. BROWNLIE, B.Sc. Hons. (Lond.), F.C.S., and H. GREEN.

FOR some time past everyone has been talking of national economy and the need for the application of scientific methods in industry. Most engineers and technical chemists are doubtless aware that one of the most shocking examples of lack of national economy is the boiler-house, in the burning of coal for the production of steam. But although this fact may be said to be generally well known, very little data has been given as to the exact *amount* of the loss from a national point of view. We have been engaged for a considerable number of years in investigating on scientific lines the working of steam boiler plants, with a view to reorganisation and the production of steam on the most economical and up-to-date lines. In this article we propose to give the exact details of the working of a hundred typical steam boiler plants, as at present worked in the industries of this country, with a view to arriving at some idea of the national loss due to out-of-date methods of steam generation.

The typical industrial boiler plant may be said to consist of Lancashire boilers, together with various accessories in the way of economisers, superheaters, mechanical stokers, smoke-preventers, various aids to chimney draught, and so on. Accordingly we have taken a hundred examples of such Lancashire boiler plants, and we have not included special boiler plants, such as power-stations, public institutions, &c. The hundred boiler plants are situated in England only, and we maintain that they are roughly typical of the whole of the industrial boiler plants of the country. The following industries are represented: cotton-mills, fourteen; engineering works, two; hat works, three; food product works, two; potteries, four; bleach works, seven; calico-print works, six; dyeing works, six; woollen-mills, sixteen; breweries, three; special textile works, three; paper-mills, sixteen; dyeing and cleaning works, four; flour-mills, three; collieries, seven; and chemical manufactories, four.

The plants are situated in almost every county in England, and they vary in size from one boiler, 24 ft. by 6 ft., to twelve boilers, 30 ft. by 9 ft., with coal bills varying from 800*l.* to 35,000*l.* per annum, whilst the working pressure varies between the limits of 12 lb. and 200 lb. per sq. in. As a further support for our claim that the hundred boiler plants are typical, we may say that we have inspected, without testing, hundreds of boiler plants, and we find that these are all being worked on more or less the same general lines. We, of course, do not pretend that the results of the working of a hundred boiler plants only enables us to judge with exact scientific accuracy as to the condition of all the boiler plants in England; but if, as we contend, the hundred plants are typical, then nevertheless we think very valuable information can be deduced as to the lack of national economy and the money that can be saved in the boiler-house.

Annexed we give the average working figures for the hundred boiler plants, obtained by adding together the essential figures of each separate plant, and taking an average. These figures cover a period of about three years, approximating 1913, 1914, and 1915. At the same time we give for comparison the actual working figures of a well-managed and up-to-date plant, as a specimen of what can be obtained by adopting scientific methods.*

Before discussing these results we will first give a short description of the methods used in carrying out the investigation of the working of the plant in each case. A detailed test of the plant was made for one working day, and a further test of one week was also carried out as a check on the figures for the coal used and the water evaporated, and to ascertain the weekly running conditions, including all week-end losses due to stoppage of plant, &c. The object of the test was to find out the exact normal every-day working conditions of the plant, particularly as regards efficiency and the cost in coal for the production of a unit of steam (evaporation of 1000 gallons of water), so that a scheme of reorganisation could be devised for the more economical production of steam. In every case the boiler-house staff worked the plant as usual, and at the end of the tests the water-level in the boilers and the general condition of the fires was the same as at the commencement.

A.—*Working-Day Test.*

—	Average of 100 Boiler Plants.	Typical Boiler Plant Run on Scientific Lines.
Type of boiler	Lancashire	Lancashire
Number of boilers	3.2 (average)	4
Grate area	115.2 sq. ft. (total)	130 sq. ft. (total)
Duration of test	10.66 hrs.	6.75 hrs.
Price of coal used	12s. 2d. per ton in fire-hole	15s. per ton in fire-hole
Amount of coal used	26,994 lb.	28,200 lb.
Analysis of coal used B.T.U.	12,680	11,980
Ash	9.3 p.c.	12.5 p.c.
Coal burnt per boiler per hour	791.3 lb.	1044.4 lb.
Coal burnt per square foot of grate area per hour	21 9 ,,	32.1 lb.
Water evaporated	192,630 lb. at 117 deg. F. 19,263 gals. (1 gal. = 10 lb.) (19,465 gals. on water-meter at 117 deg. Fahr.)	224,050 lb. at 95 deg. F. 22,405 gals. (1 gal. = 10 lb.) (22,528 gals. on water-meter at 95 deg. F.)
Water evaporated per boiler per hour	5646.9 lb.	8298 lb.
Water evaporated per square foot of grate area per hour	186.8 ,,	255.3 ,,
Water evaporated per pound of coal	7.13 lb. exact 7.21 lb (water at 117 dg. Fahr.)	7.94 lb. exact 7.98 lb. (water at 95 deg. Fahr.)
Equivalent evaporation from and at 212 deg. F. per pound of coal	8.11 lb.	9 21 lb.
Equivalent evaporation from and at 212 deg. F. per 1,000,000 B.Th.U.	639.5 ,,	768.7 ,,
Temperature of feed-water before economisers	117 deg. F.	95 deg. F.
Temperature of feed-water after economisers	226 ,,	305 ,,
Number of tubes in economiser	164	576
Percentage of coal bill saved by economisers	10.1 p.c.	18.5 p.c.
Draught in side flue	0.41 in. W.G.	0.70 in. W.G.
Draught in main flue at exit of economisers or chimney base	0.86 in. ,,	1.75 in. ,,
Temperature of flue gases before economisers	722 deg. F.	620 deg. F.
Temperature of flue gases after economisers	444 ,,	310 ,,
Percentage of CO_2 in flue gases from side flues of boilers by means of combustion recorder	7.5 p.c.	12 p.c.
Steam pressure:—		
Pounds per sq. in.	93.5 lb.	159 lb.
Pounds absolute	108 ,,	174 ,,
Temperature of saturation of steam	333.2 deg. F.	370 deg. F.
Temperature of superheated steam	369.6 ,,	540 ,,
Steam or power used as auxiliary to the production of steam	1.5 p.c. of steam raised (5 p.c. in 30 cases out of 100)	3.5 p.c. of steam raised
Thermal efficiency:—		
A. Net working efficiency of plant complete, after deducting steam or power used as auxiliary to the production of steam	62.03 p.c.	78.68 p.c.
B. Boilers only	55.65 ,,	60.99 ,,
C. Economisers only	6.24 ,,	14.16 ,,
D. Superheaters only	1.08 ,,	6.39 ,,
Cost in coal to evaporate 1000 gallons of water	91.3d. (1 gal. = 10 lb.)	100.9d. (1 gal = 10 lb.)

B. *Long Check Test.*

(One week of seven days.)

Duration	168 hours	167.4 hours
Price of coal used	12s. 2d. per ton in fire-hole.	15s. per ton in fire-hole
Amount of coal used	110.09 tons	235 tons
Water evaporated	175,100 gals.*	399,500 gals.†
Water evaporated per pound of coal	7.10 lb.*	7.59 lb.†
Cost in coal to evaporate 1000 gallons of water	91.8d.*	105.8d.†

* Actual reading on water-meter at 117 deg. F. approximately.
† Actual reading on water-meter at 95 deg. F. approximately.

Of the various items which require some explanation in detail we have:—

1. *Weight of Coal Used.*—This was taken in the usual various ways, depending on the circumstances of the case, from weighing the coal in barrows or bags, to weighing carts and railway trucks direct.

2. *Analysis of Coal.*—The sampling was carried out with the greatest care. Samples were taken every half-hour by the clock, and also every hour. At the end of the trial the hourly and half-hourly samples were broken up, thoroughly mixed, quartered, and so on as usual, several pounds being finally taken in sealed tins for analysis. There was thus obtained two entirely independent samples of the same coal. These two samples were analysed separately, and the average figures taken. If more than one quality of coal was used, each separate quality had two independent samples taken, as already described. Further, during the week's trial a sample of the coal was taken each hour, the samples mixed, and an average sample for each day analysed, making, for one quality of coal only, two samples on the day's test and seven for the week. We think by this means a very good average of the coal used was obtained. As regards the analysis, the heating value was determined by means of an oxygen bomb calorimeter (Mahler-Donkin). The bomb type of calorimeter is, of course, acknowledged to be the standard scientific instrument for accurate heat determination, and the method consists in burning the damp coal as fired in a platinum-lined gun-metal bomb in oxygen at about 450 lb. pressure per sq. in. The ignition is made inside the bomb by means of a fine platinum wire heated by outside electric contact. The bomb is covered with a known amount of water at a known temperature, and, after ignition, the rise in temperature observed with a thermometer graduated to $\frac{1}{100}$ deg. Cent. As the combustion is instantaneous and totally enclosed, the heating value is obtained direct, without any corrections being required. Further, the combustion is always complete, which is not the case with many inferior types of calorimeter. The amount of ash was determined by complete combustion in the muffle furnace, so that the figure given for the percentage of ash represents the real non-combustible matter. Ashes from a boiler fire-hole, of course, almost always contain some combustible matter.

3. *Water Evaporated.*—Various methods were used, depending on circumstances, to measure the water evaporated, but, generally, the method adopted was the use of a well-known make of pressure-type water-meter calibrated before each test, and working between the boiler-feed pump and the economisers. The old method of weighing the water direct in tanks, which was sometimes used, is, of course, very cumbersome, and almost impossible for regular weekly testing, such as is necessary on a properly-organised boiler plant. Some form of water-meter is therefore essential. Whichever type is adopted, we must strongly recommend the additional installation of a calibrated tank of, say, 500 to 1000 gallons capacity, so that the accuracy of the meter in use can be checked every week.

4. *Analysis of Feed-Water.*—Samples of the feed-water passing through the water-meter were taken every half-hour during the day's test, and a good average obtained in this way. The samples were analysed by the Wanklyn soap-test method before and after boiling, giving the permanent and temporary hardness. The soap test, although generally regarded as not very accurate by chemists, is extremely convenient for this class of work. In exceptional cases a full scientific analysis of the feed-water was carried out, giving the amount of total solids, calcium and magnesium carbonates and bicarbonates, alkalinity, &c.

5. *Temperature of Feed-Water.*—On the day's test, the temperature of the feed-water, before and after the economisers, was taken every half-hour, or oftener if the variation was considerable. We used for this purpose our own calibrated thermometers, as economiser thermometers are rarely correct after months of usage.

6. *Draught Measurement.*—On the day's test, this was taken every half-hour in the side flues, and either in the main flue after the economisers or in the chimney base. A ½-in. wrought-iron pipe was inserted into the middle of the flues, and the draught taken with an ordinary draught-gauge of the glass U-tube type.

7. *Temperature of the Flue Gases.*—For this determination a well-known make of pyrometer was used of the thermo-electric type, with platinum-iridium and platinum junction, in a porcelain tube enclosed in a steel tube, and connected through coils of calibrated wire to a voltmeter graduated direct from 212 deg. to 1500 deg. Fahr. in divisions of 20 deg. The instrument was arranged with a two-way switch, two coils of wire, and pyrometers in the flue before and after the economiser, so that the two readings could be read practically simultaneously. Before each test the instrument was calibrated by means of the vapour of some substance with a high boiling-point in a special form of iron condenser for the purpose. As usual, on the day's test readings were taken every half-hour.

8. *Percentage of CO_2 in Flue Gases.*—In each case

* In comparing the data given in the table it should be specially noted that the coal used in the plant referred to in the last column was of substantially higher cost per ton (although of inferior heating power) than that dealt with in the preceding column.

some reputable make of combustion-recorder was fitted on the plant and the percentage of CO_2 recorded at the rate of about twenty analyses per hour on a chart along with the time of the analysis. One week's run was taken in this way in each case. The samples of gas were taken from the side flues of each boiler in rotation, allowing, as a rule, about 12 hours (say 240 analyses) on each boiler, so that at the end of a week a very good average was obtained. At the present time we use a much improved type of combustion-recorder which will give, if necessary, two months' continuous record, day and night, on one chart at the rate of twenty analyses an hour. At the same time we also determined the composition of the flue gases by means of the Orsat apparatus. This was done more generally as a check on the combustion-recorder, and usually about six to ten analyses were taken during the day's test.

9. *Steam Pressure.*—On the day's test, the steam pressure was taken every half-hour, or oftener if there was a considerable fluctuation.

10. *Temperature of Superheated Steam.*—On the day's test, the temperature of the superheated steam was taken every half-hour with a calibrated mercury thermometer. Like the economiser thermometers in general use, the thermometers in use with superheaters are seldom very accurate.

11. *Auxiliary Steam.*—With regard to the steam or power used as an auxiliary to the production of steam, in the case of an engine the indicated horse-power of the engine was taken, and from the type of engine used a very good idea was obtained of the steam used. Thus, for the ordinary enclosed forced-lubrication high-speed engine in use for driving forced or induced-draught fans an average figure is 35 lb. of steam per indicated horse-power per hour. In the case of a motor drive the power used is, of course, very easily determined. The difficulty is in connection with steam used in the form of steam-jets, either under or over the fire-bars.

We have devised an apparatus for the purpose of estimating the amount of steam issuing from nozzles consisting of an enclosed cylinder connected with a long condensing coil. In determining the steam used, the steam-pipe and nozzles, or heavy casting with series of small holes, or other apparatus used, is placed bodily in the enclosed cylinder and coupled up in exactly the same manner as when under the fire-bars. The steam passes through the cylinder and coils, which are immersed in cooling water and open to the air at the end, and the steam used over a period of several hours weighed direct as condensed water. This apparatus we have found to be very simple and convenient, and gives absolutely accurate results.

(To be continued.)

THE SPECTRA OF HYDROGEN AND HELIUM.

THE obscurity concerning the spectra of hydrogen and helium, one of which elements seemed to show certain lines in stars, which had never been observed in the laboratory, has been cleared up to a certain extent since April, 1914, when Professor A. Fowler, F.R.S., dealt with this problem before the Royal Society in his Bakerian Lecture on "Series Lines in Spectra."* Discoursing on "The Spectra of Hydrogen and Helium" at the Royal Institution on Friday, the 31st ult., Professor Fowler treated the subject in a more elementary way. The investigation of the spectra of hydrogen and helium, Professor Fowler pointed out, was intimately connected with problems apparently so diverse as the constitution of the atom and the order of celestial evolution. Like hydrogen, helium now appeared to be capable of emitting one of the simplest spectra known; hydrogen showed itself in nearly every self-luminous celestial body, and helium, discovered by its yellow D_3 line in the chromosphere of the sun, long before the gas was isolated in the laboratory, was characteristic of a special class of stars. Hydrogen tubes gave two spectra; the ordinary reddish glow was characterised by the bright lines of the primary spectrum, $H\alpha$, $H\beta$, $H\delta$, &c., in the red, blue-green, blue, &c.; the less well-known bluish glow of hydrogen showed the exceedingly complicated secondary banded spectrum of many hundreds of lines; this secondary spectrum was so far unknown in stars. Which of the two spectra a discharge-tube would emit depended upon circumstances; a narrow capillary at a pressure of a few millimetres gave the primary spectrum, but sealed tubes of this kind deteriorated rapidly, and showed the secondary spectrum superposed on the primary, owing probably to the gas evolution from the electrodes; to avoid this, F. A. Gould, of the National Physical Laboratory, connected the tube with a large bulb. The secondary spectrum was so complicated that it had been ascribed to the presence of impurities; but it was no longer doubted that it really belonged to hydrogen.

The regularity of the arrangement of the primary lines had first been formulated by Balmer in 1885, according to whom the wave-length $\lambda = 3646.14\ m^2/(m^2-4)$; when the integer values 3, 4, 5 were taken for m, the λ were those of $H\alpha$, $H\beta$, $H\delta$, &c. Lines connected in this way were said to form a series, and the formula showed that there could be no member of this series of smaller wave-length than 3646.14 Angtröm units, for which m was infinite. If the formula were written so as to express wave-numbers $n = 10^8/\lambda$, or the number of waves per centimetre, then $n = 109{,}675\left(\frac{1}{2^2} - \frac{1}{m^2}\right)$; the 109,675 was the Balmer (or Rydberg) constant.

Balmer's formula permitted of calculating an infinitely great number of lines, but in the laboratory it was difficult to observe even ten members, though the addition of helium to the hydrogen brought out more ultra-violet lines (Dewar); some Huggins stars, on the other hand, showed 20 of the series lines, Dyson had observed 28 in the solar chromosphere, and Mitchell 34; nobody questioned their belonging to hydrogen.

In addition to the Balmer series of hydrogen, there was a series in the infra-red (predicted by Ritz and observed by Paschen), and a series recorded by Lyman with a Schumann spectrograph; these two series were simply related to the Balmer series. In other spectra, Kayser and Runge, Rydberg, and others had discovered other series, several series being mostly so superposed that their distinction was difficult. There were usually three chief series, designated in the order of brightness as the principal P, the sharp S, and the diffuse D series. Balmer's formula had slightly to be modified to fit these series, and Rydberg wrote the formula: $n = A - N/(m+\mu)^2$, where A was the limit of the series and N the Balmer-Rydberg constant. The corrected value of the Rydberg constant was 109,679.22, according to the careful determination by W. E. Curtis, of the Imperial College of Science. Rydberg's formula was only approximate, yet very useful; it led to simple formulæ for the P, S and D series, and if either the P or the S series were known, the other could be calculated. Further formulæ had been deduced by Ritz with the aid of the combination principle.

Passing to the spectrum of helium, Professor Fowler remarked that Runge and Paschen distinguished six series in its primary line spectrum, the P, S, D series of very close doublets, and the P^1, S^1, D^1 series of single lines. There being no recognised connection between the two sets of series, the helium had been supposed to be a mixture of two gases, and the P^1 series had been ascribed to "parhelium." That belief had been strengthened by the observation that the ordinary yellow glow of a helium tube at 1 cm. pressure changed into a greenish glow at 1 mm. pressure; but helium stood by no means alone in this respect, and parhelium had been abandoned. Like hydrogen, helium also gave a very complex secondary spectrum, which was simultaneously discovered by Goldstein and by Curtis; it was a distinctly, but peculiarly banded spectrum, and was seen in the wide parts of tubes containing helium at rather high pressure with a small condenser and spark-gap, but had not yet observed in stars; in these respects helium resembled hydrogen.

Professor Fowler then came to the chapter in the story of the spectra of hydrogen and helium which had caused so much discussion. In 1896 Pickering discovered in the star ζ Puppis lines intermediate between the hydrogen series of Balmer, but apparently converging to the same limit as the Balmer series. Pickering at once suggested that the new series might also belong to hydrogen, and Rydberg calculated that the Balmer lines represented the diffuse series, and the Pickering lines the sharp series of hydrogen; from the latter he deduced the principal series; that this can be done has already been stated. This new P series should have a blue line, near 4688, and this should be very bright, being the first member of a principal series, whilst the other members would probably be too faint to penetrate through our atmosphere. Now a bright line, 4686, was already known in the Wolf-Rayet stars (in company with Pickering lines), in many nebulæ, and also in ζ Puppis. The example of the beautiful ring nebula of Lyra was peculiarly interesting. Arranging his spectroscopic slit as a vertical diameter, cutting the nebular ring above and below, and passing through the dark centre, Max Wolf found the line 4686 in the dark centre. But as this line and the Pickering series had never been observed in the laboratory, it was suggested that they might belong to a peculiar hydrogen at very high temperature, which N. Lockyer called "proto-hydrogen," and Miss Clerke "cosmic hydrogen." Now Professor Fowler himself had observed a faint line 4686 in the chromosphere in 1893; experimenting later, he found it in helium tubes, and taking up one of those old tubes in 1912 again, he noticed that the faint line would come out very strong at relatively high gas pressures and with strong (condenser) discharges. Subsequently Professor Fowler observed other Rydberg lines in the ultra-violet, but in helium, not in hydrogen tubes, and he had therefore found more than he bargained for. Since, however, hydrogen would turn up in all tubes, no matter what gas they contained, he assigned the new lines with Rydberg to hydrogen.

Yet, Dr. Fowler proceeded, the position had not been satisfactory when new light was thrown on the subject in 1913 by Bohr's theory of the constitution of the atom. Applying Planck's quantum theory to the Rutherford model of the hydrogen atom (positive nucleus, round which an electron moves in an orbit), Bohr gave Balmer's formula a form in which it included the 4686 and Pickering lines. In its ordinary planetary motion (stationary state) the electron was not to radiate light, but when driven out of its orbit by electric discharges into another stationary state, it would, on its return-jump to the first state, radiate definite amounts of energy, which would determine the frequency, and thus the position of the respective line in the spectrum. The helium atom contained a nucleus of four times the mass of the hydrogen atom, and two electrons revolved round it; moderate discharges detached one electron, which, on its return, gave the ordinary spectrum, while strong discharges detached both the electrons. When only one of these electrons was regained by the nucleus (the simpler case so far worked out), the formula of Bohr for helium was identical with that for hydrogen, except that instead of the N constant another constant, $N^1 = 4\,N$, had to be introduced; and it was remarkable that when Bohr allowed for the mass of the nucleus (which he had not at first done), the slight difference between the observed and calculated (Rydberg) lines vanished. Thus the new helium tube lines had to be attributed to helium, and not to hydrogen.

In subsequent experiments the questionable lines had, indeed, been found by Evans, Stark, and himself in helium tubes which seemed to be quite free from hydrogen. The study of the enhanced lines—intense lines, only becoming visible with the spark discharge—of magnesium further supported the view that two kinds of series should be distinguished:—(1) Series of the arc type with the Rydberg constant N; (2) series of the spark type, constant $N^1 = 4\,N$, giving twice as many lines. In the case of hydrogen Bohr's formula $n = N\left(\frac{1}{p^2} - \frac{1}{m^2}\right)$ gave the infra-red series for $p = 3$, the Balmer series for $p = 2$, the Schumann series for $p = 1$, whilst in the case of proto-helium—the name used to distinguish this helium from ordinary helium—the formula was $n = N^1\left(\frac{1}{p^2} - \frac{1}{m^2}\right)$, and $p = 4$ gave the Pickering series, and $p = 3$ the 4686 series. The return of one detached electron seemed to give rise to the usual arc spectrum, the return of one of two electrons to the spark type. Relations between the arc and spark types of spectra of the same element did not appear to exist; the two types, in fact, looked as if belonging to different elements.

As now the 4686 series was clearly of the spark type, it could not belong to the arc series of hydrogen, and must be assigned to helium. On

* See ENGINEERING, vol. xcvii., page 493.

the older theories the name "proto-helium" would have implied that the atoms themselves were broken up; on the modern theories a proto-element merely had one electron removed, and its mass was only very slightly reduced. To test this point T. R. Merton had made comparative (interferometer) measurements of the breadth of line 4686 and other helium lines. According to Rayleigh the breadth of a spectrum line chiefly depended upon the Doppler effects due to the motion of its luminous particles, whose velocities depended upon the atomic mass and temperature of the gas. Merton found the line 4686 so much wider than the others as to indicate only 0.1 of the atomic weight of helium, if the theory of broadening were complete; but Bohr credited the 4686 particles with an increased velocity, because they carried an excess charge in an electric field. The chief outstanding difficulty concerned the positions of the Pickering series lines; but E. J. Evans (Manchester) had photographed some of these lines exactly in the positions predicted by Bohr, and this seemed to be confirmed by Paschen. Bohr's theory had, at any rate, proved brilliantly successful as regards hydrogen and proto-helium, though Nicholson's attempt to extend this theory to the ordinary spectrum of helium had so far failed. The lines now assigned to the simplified form of helium were of special astrophysical interest, since they occurred, together with the ordinary helium lines, in nebulæ and Wolf-Rayet stars. These investigations also supported the assumption that nebulæ and Wolf-Rayet stars stood next to each other in stellar evolution, and that the nebulæ condensed into Wolf-Rayet stars. A good deal of mystery still surrounded these questions; yet it was surprising that the laboratory resources had proved sufficient to reproduce so many spectral lines of celestial bodies.

THE PARIS MOTOR-BUSES.

In a former article* we pointed out the effect which the war was having upon the travelling facilities within the boundaries of the French metropolis. In regard more particularly to the omnibus service, hostilities were declared when this service was being afforded by motor vehicles which were giving complete satisfaction; the chassis, motors, and tyres had gradually been improved; breakdowns had ceased to occur; expenditure was on the decrease and receipts were gradually rising. The omnibus service was drawing to itself a very large proportion of the passengers who hitherto had favoured the underground metropolitan railway systems, notwithstanding the fact that this service has always been surrounded with difficulties which are not met with in London. Many of the Paris streets have comparatively heavy gradients, and the service only extending within the fortifications, the distances are small, 7 km. (4.3 miles) hardly ever being exceeded, resulting in the standing of the vehicles at each terminus, and a loss of time large in proportion to the running time.

When the war broke out, the whole of the motor-buses were commandeered for military use exclusively, and the Paris service ceased completely. A few months ago, when it was decided to start in Paris a reduced motor-bus service, the Paris General Omnibus Company, which controls the traffic, found that it could not do better than adopt the type of vehicle which was finally accepted in the middle of 1914. Vehicles for this reduced service were put in hand, but they have not been placed on the Paris streets, for the military authorities commandeer the new vehicles as fast as they are built.

A large proportion of the motor-buses which had been taken over by the French War Department at the outbreak of hostilities were, on their return to Paris from the war-zone, converted with the object of still further facilitating the transport of men and food-stuffs. For the latter service, the whole of the seating accommodation was removed, the glass panes were replaced by wire-netting, and the roof was provided with strong hooks. The vehicles which were built more recently, with a view to ensure the limited service referred to, were finished in the same way by order of the military authorities. The manner in which all the vehicles have been able to withstand the hard usage they have received and are still receiving in the hands of the military men is indeed remarkable; it affords a proof of the excellence of their design and manufacture, and renders the following brief description of their component parts specially interesting.

Prior to the year 1906 the company owned a number of double-decked motor-buses, carrying 32 passengers, mounted on a Schneider chassis. The motor was a four-cylindered Schneider, the cylinders having a bore of 125 mm. (4.9 in.) and a stroke of 140 mm. (5.5 in.). The engines developed 30 horse-power at 900 revolutions per minute. This type of vehicle was quite satisfactory; but it was found that much delay was caused owing to the time taken by passengers in leaving and taking their seats. The chassis weighed 3190 kg. (3 tons 2 cwt. 3 qr.), of which 1690 kg. (1 ton 13 cwt. 1 qr.) was on the front axle. The omnibus when empty had a total weight of 5060 kg. (4 tons 19 cwt. 2 qr.), of which 2030 kg. (1 ton 19 cwt. 3 qr.) was carried on the front axle. With the total complement of passengers the weight was 7270 kg. (7 tons 3 cwt.). The maximum speed on a level was 22 km. (13.7 miles) per hour. The second speed was 13 km. (8.1 miles), and the first speed 6.5 km. (4.05 miles) per hour.

Since the company had to adopt mechanical traction on the whole of its routes, numerous trials were carried out with several types of vehicles. One of these was an omnibus seating 23 passengers on seats placed longitudinally. Another was a 34-seat vehicle mounted on a Schneider chassis; this latter has proved the prototype of the one finally adopted. A third model had 21 seats, and was carried on wheels with pneumatic tyres, each rear wheel being fitted with three tyres, two of which were non-skids. It was not long before it was found that the tyres burst rapidly, or else were very soon out, thus rendering the service most irregular. These vehicles weighed 5500 kg. (5 tons 8 cwt.) each with their full complement of passengers. Another motor-bus was then tried, seating 28 passengers, having a body 2.30 m. (7 ft. 7 in.) in width, with side entrance close to the rear end; then a further design carrying 30 passengers, and having a rear platform on a lower level, access to which was had by a step on the centre line of the vehicle.

All these and further experiments led to the final type. They showed that the body should have a minimum width of 2.30 metres in order to give sufficient room to render the vehicle a remunerative one. The platform above referred to, placed in the rear on a lower level, was maintained. The double-deck was done away with entirely, and the number of seats was made to vary between 35 and 30, according to the route. For a certain number of the new vehicles the chassis taken from the old double-decked omnibuses were utilised, after being reconstructed where necessary. The chassis for the 35-seat vehicles are built by Messrs. Schneider at their Havre works, and those for the 31-seat vehicles by Messrs. de Dion-Bouton, of Puteaux, near Paris.

The motor-bus carrying 35 passengers, mounted on a Schneider chassis, is driven by a four-cylinder engine of the dimensions given above, built by the same firm. The chassis, engine and gear are illustrated in Figs. 1 to 13, on Plate XXXII. The chassis is shown in side elevation and plan in Figs. 1 and 2; Fig. 3 is a front end view. The differential gear is illustrated in Fig. 4, and is of the usual bevel type. Figs. 5 to 7 give details of the steering-gear.

The engine, which is illustrated in Figs. 8 to 10, is carried by two cross-members. The cylinders are of the T type, and are lubricated on the splash principle. The cam-shaft is gear-driven and has keyed-on cams. The inlet-valves are operated by means of long tappets and overhead levers. The ignition is by means of high-tension magneto. The cooling is by thermo-syphon, the radiator and fan being mounted on the front of the chassis. To prevent damage to the copper tubes of the radiator, an aluminium star-piece protector is fitted, as shown in Fig. 3. The power is transmitted through a Hele-Shaw clutch to the gear-box, which provides three forward speeds, the third speed being a direct drive, and one reverse. The speed-gear box is shown in Figs. 11 and 12. The final drive on the back wheels is by an annular spur-gear, the outer rings being bolted to the wheels, as illustrated in Fig. 13.

The steering-gear, as shown in Figs. 5 to 7, is of the screw-and-nut type, and is on the left-hand side. The vehicle has two brakes—a differential brake actuated by a pedal, which also disengages the clutch, and a lever-brake acting on brake-drums fixed to the rear wheels. The shoes of the rear brakes are wood-lined. The wheels are of wood, and are manufactured in the General Omnibus Company's works, the spokes being made of acacia and the rim of elm; the naves are of steel, and are fitted with phosphor-bronze bushes. The front wheels, which are provided with single rubber tyres, are 0.900 m. (35.4 in.) in diameter, and the rear wheels, which are provided with twin tyres, are 0.950 m. (37.4 in.). The chassis weighs 3350 kg. (3 tons 5 cwt. 3 qr.), of which 1750 kg. (1 ton 14 cwt.) is carried on the front axle. The motor-bus, empty and in running order, weighs 5100 kg. (5 tons 1 qr.), of which 2150 kg. (2 tons 2 cwt. 1 qr.) is on the front axle, and 2950 kg. (2 tons 18 cwt.) on the back axle. With the full complement of passengers the weight is 7800 kg. (7 tons 13 cwt. 1 qr.), of which 5300 kg. (5 tons 4 cwt. 1 qr.) is carried on the back axle. The chassis is 7.567 m. (24 ft. 10 in.) in total length; the width of the front part is 0.928 m. (36.5 in.), and the rear portion 2.160 m. (7 ft. 1 in.). The wheel-base is 4.450 m. (14 ft. 7 in.). The over-all width of the back axle is 2.178 m. (7 ft. 2 in.), and over the front axle caps is 2.006 m. (6 ft. 7 in.). With the engine running at 1000 revolutions per minute, the vehicle travels, on the three different speeds, at 6.5 km., 12.7 km., and 22.7 km. (4.05, 7.9, and 14 miles) per hour.

The older Schneider chassis, which carried double-decked motor-buses, and which have been lengthened by the addition of a platform built of angle bars, are fitted with a Schneider engine similar to the one above referred to. The chassis has a total length of 6 660 m. (21 ft. 10 in.), a width of 0.855 m. (33.6 in.) in front and 2.160 m. (7 ft. 1 in.) in the rear. The wheel base is 3.650 m. (12 ft.). The chassis alone weighs 3350 kg. (3 tons 5 cwt. 3 qr.), of which 1760 kg. (1 ton 14 cwt. 2 qr.) is carried on the front axle. The motor-bus has seating accommodation for 30 passengers, and weighs empty 4945 kg. (4 tons 17 cwt. 1 qr.), of which 2035 kg. (2 tons) is carried on the front axle. With its full complement of passengers the weight is 7035 kg. (6 tons 18 cwt. 2 qr.), of which 2225 kg. (2 tons 3 cwt. 3 qr.) is on the front axle. The speeds are 6.5 km., 12.7 km., and 22.7 km. (4.05, 7.9, and 14 miles) per hour. The gear is generally similar to that of the other type of Schneider vehicle.

The bodies of these vehicles need no special comment, since they may be considered more or less as makeshifts. One type of vehicle has seating accommodation for 31 passengers—12 first-class and 19 second-class; another has 30 seats—8 first-class and 22 second-class. Further types can seat 35 passengers, either 16 first-class and 19 second-class, or 12 first-class and 23 second-class, since it was found that on many of the omnibus lines the first-class passengers were decreasing, contrary to what occurred with the horse-drawn vehicles. The body-frame is of oak, the curved ribs of ash, the roof of pine and the floor-grating of elm. The first-class seats are generally of mahogany and the second-class seats of pitch-pine. The total weight of a body, complete with all fittings, is from 1600 kg. to 1800 kg. (about 1 ton 13 cwt.). Means have been provided for heating the omnibuses with the exhaust gases from the engine, for which purpose the gases are made to flow through aluminium foot-warmers, baffle-plates suitably fitted in the exhaust-pipes and a disc-valve on the silencer regulate the temperature of each foot-warmer. The foot-warmers have not always been found perfectly gas-tight. Lighting in the Paris service is by acetylene; the same method is followed on the battle-field when lighting can be resorted to without any risk. At first the gas was raised in a calcium-carbide generator, but the piping rapidly clogged-up and the generator frequently leaked and was difficult and costly of maintenance. At the present time dissolved acetylene is exclusively used; gas-cylinders are fitted to the vehicle, containing purified acetylene gas, a porous substance and acetone. The gas is supplied to the lamps at a constant pressure of 20 cm. (7.8 in.) of water by means of a pressure regulator. The cylinders contain a supply for a two days' service.

When the motor-buses were in regular service in Paris they were inspected by a mechanic on their reaching each terminus, and also every night on their reaching the garage. When a vehicle had covered 40,000 km. (25,000 miles) it was taken to the shops and completely overhauled; the body was removed, the chassis thoroughly inspected, and rivets which had become loose replaced by new ones. The engine, speed-gear, differential-gear, and other parts of the mechanism were taken to pieces, readjusted, and tested. The vehicle was then re-erected and tested before being returned to service. The cost of maintaining the vehicles in perfect working order was found to amount to 0.13 franc per kilometre (16s. per 100 miles) for the chassis and motors, and to 0.03 franc (3s. 10d. per 100 miles) for the body. The cost of other items works out as follows:—0.12 franc (15s. 5d. per 100 miles) for the tyres; 0.0265 franc (3s. 5d. per 100 miles) for washing, lighting and heating; 0.2125 franc (27s. 4d. per 100 miles) for the various fuels. At first alcohol carburetted with 50 per cent. of benzol was used; later benzol alone was adopted, notwithstanding certain disadvantages, such as less rapid starting in cold weather and fouling of the sparking-plug. The motor-fuel consumption per vehicle was found to be, on an average, 0.500 litre per kilometre (0.176 gal. per mile) for 90 per cent. benzol having a density of 0.880; 0.525 litre (0.180 gal. per mile) for petrol having a density of, say, 0.745, and 0.575 litre (0.2 gal. per mile) for alcohol carburetted with 50 per cent. of benzol. The expenditure on lubricating oil, grease and cotton-waste amounted to 0.0210 franc per kilometre (2s. 9d. per 100 miles); the drivers' wages amounted to 0.10 franc (12s. 10d. per 100 miles), and the dépôt charges to 0.06 franc (7s. 9d. per 100 miles). The total gave 0.70 franc per kilometre (89s. 4d. per 100 miles), which does not include the reserve for renewals, the ticket collectors' and examiners' wages, general charges, taxes, insurance, accidents and maintenance of buildings.

At the commencement of the motor-bus service in Paris the gross receipts were found to be 0.892 franc

* See ENGINEERING, vol. c., page 474.

18,900-K.V.A. SINGLE-PHASE ELECTRIC GENERATOR; RJUKAN II. POWER-STATION.

CONSTRUCTED BY THE SWEDISH ELECTRICAL COMPANY, ENGINEERS, VASTERAS.

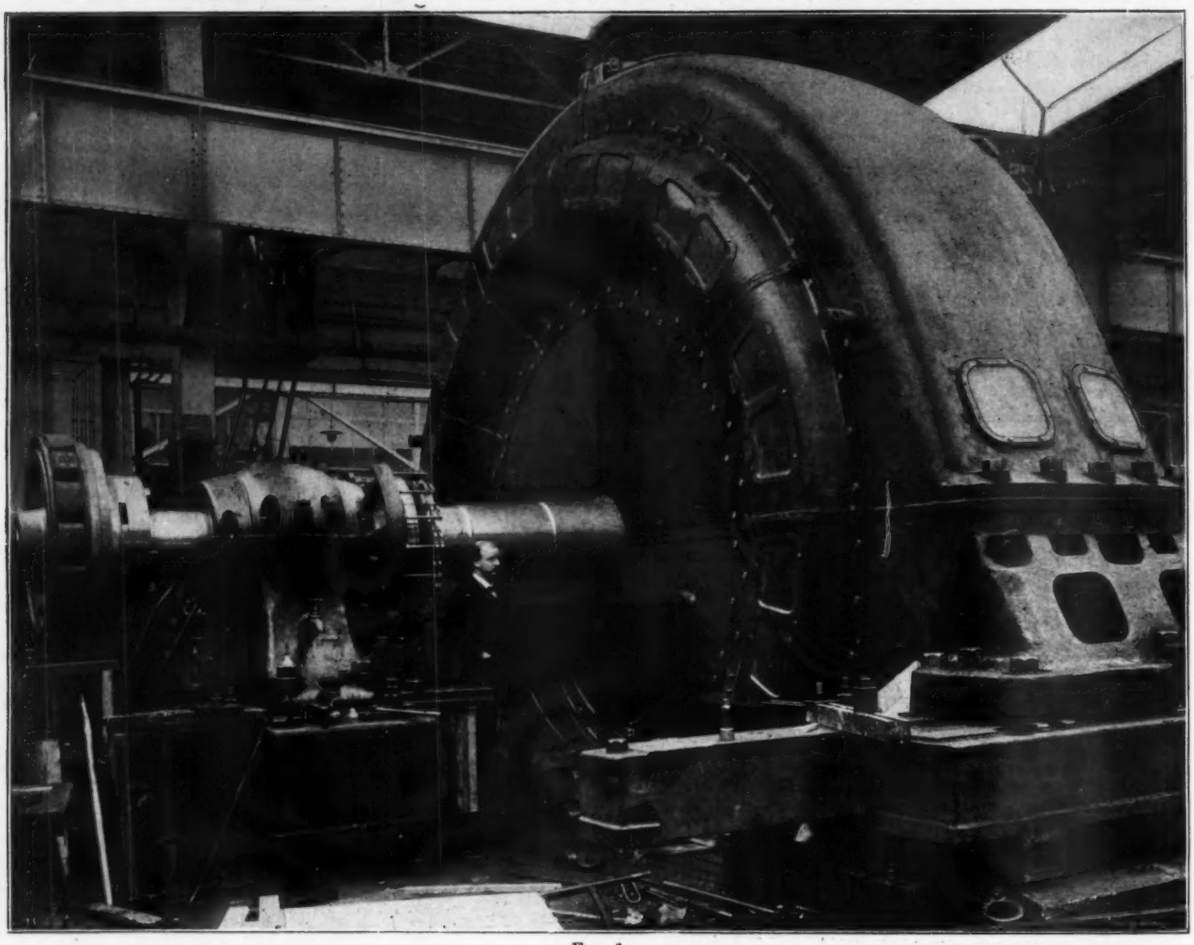


FIG. 1.

per kilometre (1s. 1d. per mile), 0.144 franc (1.4d.) per passenger and 0.156 franc (1.5d.) per seat available, whilst the three corresponding figures in the case of the horse-drawn vehicles were 0.612 franc per kilometre (9.8d. per mile), 0.154 franc per passenger and 0.113 franc per seat (1.5d. and 1.1d.). The motor-buses carried over 6180 passengers per kilometre per year, whilst in the horse-drawn vehicles the corresponding number was 3970. In 1913 the company carried 426,000,000 passengers in their motor-buses, the figure for 1912 being about 366,000,000, whilst in 1909, when the improvement in the service was commencing, it was under 254,000,000. However, in the periods under consideration the number of car-kilometres run rose from 48,000,000 to 67,000,000, the receipts rising from 44,000,000 to 58,000,000 francs.

(To be continued.)

THREE-PHASE GENERATORS FOR RJUKAN II. POWER-STATION AT SAAHEIM, NORWAY.

IN 1905 the capacity of the largest water-turbine-driven electric generator was only 5000 k.v.a., but since then, in rapid succession, water-power installations have been completed with many times that capacity. Most of these generators have been manufactured in the engineering works of the more important countries, but, nevertheless, the Swedish electrical industry has always maintained its place in the front rank. Thus the generators at the Svülgfos, the Rjukan, and the Tröllhattan hydro-electric power-stations, which were considered the largest in the world at the time, were all of Swedish manufacture. Recently the General Swedish Electric Company at Vasteras has supplied to the second Rjukan power-station at Saaheim, in Norway, six generators which leave those hitherto made a long way behind as regards size, and which, for the present, may claim to be the largest three-phase generators built for water-turbines. Some particulars about their construction, and the results of the tests, together with the views on this and the opposite page, and also on page 352, will therefore be of interest.

In consequence of the method of manufacture of nitrates by the Birkeland-Eyde system, which involves the transmission of energy direct from the machines to the furnaces without any transformation, the generator units were designed for a continuous maximum output of 18,900 k.v.a., with 9500 volts, 250 revolutions per minute, 50 periods, and $\cos \phi = 0.65$.

In contrast to the machines previously made for the Rjukan station, those under review are constructed as single-phase generators. Otherwise the construction does not in its main features deviate from that generally followed, with stationary armature and rotating magnet field, but, on account of the size of the machines, a number of special arrangements have been necessary. Thus both the stators (Fig. 8, page 352) and the rotors (Figs. 9 and 10), for convenience of transport, have been built in several pieces. The exigencies of the means of transport did not allow of heavier pieces than 25 tons, nor of sizes exceeding the ordinary railway loading gauge. Further, partly to keep the noise in the power-station within reasonable limits, but principally for the sake of ventilation, the generators are completely enclosed.

The machines are erected in pits of such a size that the height of the shaft above the floor of the power-station is about 1 m. (Fig. 2). The excavations, in addition, are so large in an axial direction that the trunks for the intake of the cooling air and the central casings having been removed; the stators can be shifted sideways so far that the rotor becomes fully accessible without lifting the upper half of the stator.

So as to render all the parts of the stator winding easily accessible, the stator, after its detachable feet have been removed, can be turned round on rollers provided for the purpose. Otherwise the construction is arranged in the usual manner, with separate foundation-plates for the stator and the bearings (Figs. 2 and 3). In addition, one bearing is electrically insulated, both from its foundation and from all the oil and cooling-water pipe-lines connected to it.

The armature of the direct-coupled exciter is placed at some considerable distance from the generator bearing. This has been done so as to make it possible to place a lifting-jack under the shaft, between the exciter and the bearing, so that the dismantling of the generator bearing can be effected without removing the exciter. The stator of the latter stands by itself on a separate foundation-plate.

The stator-frame of the three-phase generator is entirely of cast-iron. It is divided into four parts, and forms a collecting trunk for the cooling air which flows from the ventilation channels in the foundation-plate. The four parts are attached to each other by bolts and screws. The casing is fitted with apertures, of which those above the level of the floor, as a rule, are closed with doors, which can be removed if it be required to let the warm air direct into the generator. The apertures on the lower half, on the other hand, are without doors. Normally all the warm air is let out through these to the outlet channels of the ventilating system.

The coverings surrounding the windings are attached to the stator-frame. They are of cast iron, as this is better than sheet metal for reducing the roar from the interior of the machine. The casings are fitted with sheet-iron doors to facilitate inspection. The flat shields, which close the opening round the axle, are also of cast iron. On the one side the lower of these shields is formed into a mouth-piece for connection with the open air-channel.

The armature is composed of an alloy metal, insulated by paper. It is attached to the frame in the usual manner by means of swallow-tail wedges, and

18,900-K.V.A. SINGLE-PHASE ELECTRIC GENERATOR; RJUKAN II. POWER-STATION.

CONSTRUCTED BY THE SWEDISH ELECTRICAL COMPANY, ENGINEERS, VASTERAS.

Fig. 2.

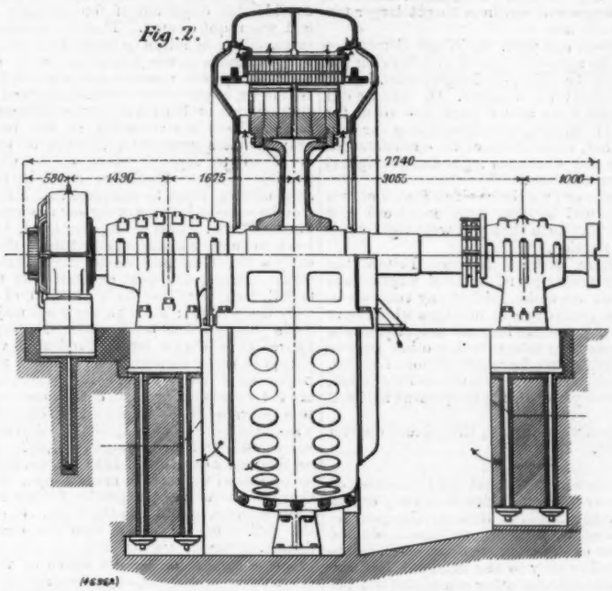
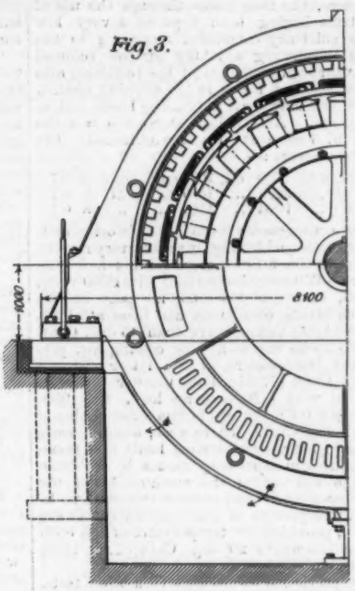


Fig. 3.



held together axially by pressed flanges and insulated bolts. The pressed flanges are at the same time so shaped that they can serve as bases for the winding supports. The unusually long armature is fitted with numerous ventilation channels. On account of the large quantity of core-plates which had to be dealt with—about 40 tons per machine—special tools were constructed, so that an entire core could be dealt with in one operation. As a matter of curiosity, it may be mentioned that each machine contains about 34,000 core segments, laid in by hand.

The armature winding comprises two plane windings divided into three slots per pole and phase, two bars per slot. Each bar in its turn is divided into a number of parts, of which those nearest the air-gap are stranded. The eddy-current losses have thereby been kept so low that the losses recorded at the short-circuit tests only exceeded those calculated from the resistance measurements by about 35 per cent. For the insulation of the windings, micanite has mostly been used. The bars are individually insulated by means of cotton windings, and, after impregnation, were laid in the micanite tubes. The greatest care has been taken to prevent all possibility of ozone or nitric acid being formed within the bars. The two bars in the same slot are separated by micanite insulation.

In addition to the windings being well protected, unusually stringent insulation tests were insisted upon in connection with the working voltage. Thus the tests between two neighbouring bars in the same slot were made with 12,000 volts for 10 seconds in the cold state, and between the phases and between the conductors and the iron with 30,000 volts for 60 seconds, all with 50-period sinusoidal alternate current. The tests undertaken were exceedingly satisfactory. There certainly were some difficulties to begin with regarding the 30,000-volt tests, because creeping took place across the insulation collars of the winding support; but these having been altered to a more suitable shape, and the insulation of the support otherwise having been somewhat strengthened, the test voltage was found to bear increasing a fair amount beyond the 30,000 volts without cross-conduction taking place.

Outside the core-plates the two bars in the same are insulated separately. The insulating material is sterling plastic cloth or similar material. Each winding group is fitted with two supports, which, on the coupling side, also support the connecting wires.

The rotor is divided into discs, which are held together by means of screws. The poles and the ring are in one piece, of Siemens-Martin steel. The division has been made so as to facilitate manufacture and transport. The pole-shoes are laminated, so as to reduce the losses on account of the open slots, and attached to the poles by means of screws. On account of the high peripheral speed with the normal number of revolutions, 60 m. (197 ft.) per second, and the consequent large centrifugal stress, the greatest care had to be taken in the fastening of them. Owing to the way this has been done, the stress on the

Fig. 4. MAGNETISING & SHORT CIRCUIT CURVES.

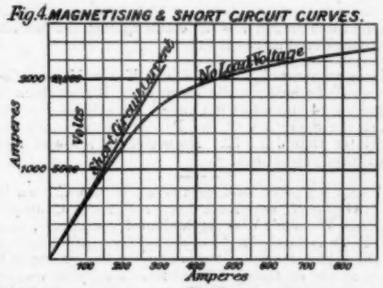


Fig. 5. LOSS CURVES. *Fig. 7.* RUNNING OUT CURVE.

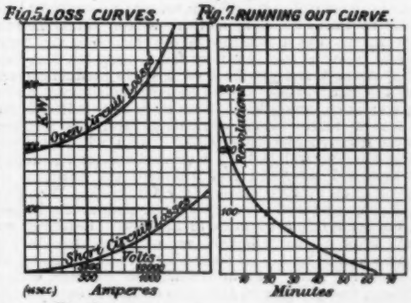
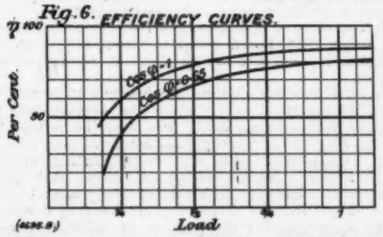


Fig. 6. EFFICIENCY CURVES.



screws, even under the most unfavourable conditions, is not excessive.

The magnet winding consists of copper tape set edgewise, and insulated in the usual manner by means of paper. Each pole has 51 windings. The insulation between the windings has been tested with a voltage 50 times higher than the usual working voltage, and between the winding and the iron with 2000 volts for 1 minute. The normal exciting pressure is 220 volts.

On account of the considerable distance between the bearings, consequent upon the arrangement for shifting the stator sideways, the shaft had to be made specially strong. It is hollow through its entire length, and the core taken out in the boring was used for obtaining test-pieces. For coupling with the turbine-shaft, the generator-shaft has a flange forged with it.

The contact-rings are of cast iron. There are five pairs of brushes on each ring, supported by a brush-holder arrangement attached to the bearing-frame. On machines with hollow shafts, the conductors between the contact-rings and the rotor are often placed inside the shaft. Insulation mishaps, however, easily occur, on account of the more or less sharp bends, which are unavoidable in this arrangement. On this machine the conductors therefore are placed in a separate slot, formed for this purpose on the surface of the shaft, and protected by means of wedges.

The bearings are of the ordinary type, with spherical brasses, lined with best white metal, and arranged for water-cooling and forced lubrication. As already mentioned, the requisite quantity of cooling air for these machines is about 20 cub. m. (706 cub. ft.) per second. This quantity of air is sucked into the generator by the fan wings placed on both sides of the rotor, which have both to draw the air through the fixed system of inlet channels and to drive it through the machine and the outlet channels into the open. The fresh air is taken in immediately below the shaft on the one side of the machine, from whence it passes partly through the fans to the cores and windings, and partly through a wide channel in the centre of the rotor. Although the air is only admitted from one side, no material differences in temperature between the two sides of the machines have been traced.

The moment of inertia of the flywheel is proportional to $A D^2$, where A denotes the weight in kilogrammes, and D the diameter in metres. For good speed regulation it is found that the value of $A D^2$ should not be less than 750,000 kgm.^{2}, but for mechanical reasons the rotor, however, has been so constructed that the value actually somewhat exceeds 1,000,000 kgm.^{2}.

The complete machine weighs about 200 tons, of which about 90 tons are in the stator part and 80 tons in the rotor, including the shaft.

For testing the machines a special two-speed asynchronous motor was constructed of normally 1500-650 horse-power, 500-250 revolutions, 50 periods, and 380 volts, intended for direct coupling to the generator. The tests gave altogether satisfactory results, and showed that all the stringent demands had been fully complied with. Fig. 4 shows the magnetising and short-circuit curves of the tests. The increase of voltage was guaranteed at a maximum of 25 per cent. at 8600 volts, 1050 amperes, and $\cos \phi = 0.65$. According to the test it is calculated as 21 per cent. At the same time the fall of voltage was guaranteed to reach 45 per cent. with the same load; this figure, too, came out well. The losses measured simultaneously with the above-mentioned curves are shown in Fig. 5. On account of special fans used in the test, the friction losses were proportionately very large, amounting in kilowatts to about 1 per cent. of the machine's k.v.a.,

whilst on other similarly shaped machines, constructed for the same number of revolutions, 0.75 to 0.80 per cent. generally was obtained. The short-circuit losses are guaranteed at a maximum of 1.6, the ohm ones. The open-circuit losses mostly consist of friction losses, the iron losses through the use of alloy core-plates having been kept at a very low figure. The efficiency calculated according to the tests, without deducting anything for the reduced friction losses through exchange of the test-fans, also comprises the rheostat losses in the exciting circuit. Fig. 6 shows the efficiency at various loads and at maximum voltage. At full load and cos $\phi = 1$ the high value of 97.6 per cent. has been obtained. The guaranteed values were :—

96 per cent.	with	8600	volt,	1050	amp.	cos ϕ	= 0.7
95.75	,,	,, 9000	,,	1050	,,	,,	= 0.7
95.75	,,	,, 9500	,,	1150	,,	,,	= 0.7

These have consequently been satisfactorily met.

Also the heat tests yielded highly satisfactory results. In this connection the following guarantees had been stipulated for :—With continuous load with 8600 volts, 1050 amperes, and cos $\phi = 0.65$, no part of the machine, when stable conditions had been attained, should have a higher temperature than 45 deg. Cent. (81 deg. Fahr.) above the in-flowing cooling air, provided that the temperature of the latter did not exceed 25 deg. Cent. (77 deg. Fahr.) under the same conditions; but with 1150 amperes load, with 9500 volts, and cos $\phi = 0.65$, the rise in temperature should not exceed 55 deg. Cent. There were, besides, some special demands for unsymmetrical loads and maximum temperatures measured by means of a thermo element in the interior of the machine. For the bearings the maximum temperature rise was to be 50 deg. Cent., irrespective of the temperature in the machinery hall, provided the temperature of the cooling water was not above 20 deg. Cent. All these guarantees were fulfilled.

Besides the previously mentioned insulation tests, the machine was run with 50 per cent. over-voltage for three minutes. In addition a short-circuit test was undertaken with full number of revolutions, and an exciting current corresponding to the maximum load, without it in the least seeming to affect the machine. Generally this test is attended by noticeable vibration phenomena. Had it not been shown in other ways that the short-circuit had actually taken place, one would have been tempted to think that some accidental contact had happened, the mechanical effects being so imperceptible.

All other tests having been made, the particularly exacting over-speed test was undertaken. For different reasons it was prolonged considerably beyond the stipulations of the contract—30 minutes with 80 per cent. over-speed—the machine in reality being run for more than an hour, the over-speed varying from 50 per cent. to 80 per cent.; the latter percentage prevailed for the last half-hour. The rotor at this test having to be in its final state, the fans were not removed. The loss of efficiency, in spite of the air-intake being closed, of course was material, and amounted with full over-speed to about 830 kw. transmitted to the generator axis. Added to this were the other losses in the testing-room machinery, so that the aggregate amounted to 900 kw. to 1000 kw. during the three hours the test altogether lasted. As the losses are caused principally by air-friction, it will readily be understood that the air enclosed in the machine would be materially heated, and the over-temperature of the air escaping from several apertures was about 30 deg. Cent. By means of electric braking the generator was soon brought to a standstill, otherwise it would have taken more than an hour. The running-out curve seen in Fig. 7 shows how the generator behaves when, without magnetising, it is left to come to a standstill by itself.

Although these generators may only be looked upon as a milestone in the progress of electric plant, they signify the furthest point so far reached, and are a very distinct credit to Swedish electrical industry.

INDUSTRIAL NOTES.

THE average net selling price of No. 3 Cleveland pig-iron for the three months ended March 31 last was certified last Friday, the 7th inst., at 72s. 11.28d. per ton, as compared with 67s. 4·16d. per ton for the previous quarter, equal to an advance of 5s. 7.12d. per ton. This means, as from the 1st inst., an advance of 7 per cent. in blastfurnacemen's wages; the advance raises wages to 51 per cent. above the standard.

The Wages Board of the Northumberland Miners' Association issued last Saturday their quarterly ascertainment upon the wages question, together with a report which states the following :—

"The first month of another quarter has now almost passed, and the high price of coal, probably never reached previously during the lifetime of even the oldest amongst us, is maintained. What change may take place in the coal market during the next two months is difficult to forecast, but if the March prices continue, the ascertainment next time will show a still further increase.

"What is true of the price of coal is also true of the price of other commodities, consequently the increase in wages is still far from meeting the increase in the cost of living. We are also afraid that this balance against wages will continue to get larger the longer the war continues.

"When, in June of last year, the Wages Committee took upon itself the responsibility of withdrawing the notice to terminate the sliding-scale agreement, it met with a good deal of adverse criticism. Of that we did not complain, as we were aware there was room for grave difference of opinion, notwithstanding our own clear conviction that, under the peculiar circumstances then existing, we did what was right in the highest interests of all our members.

"In the light of our experience since that time, we feel sure that you will be even more convinced now than you were at that time that you were right when you confirmed our action.

"In every mining district in Great Britain the price of coal has gone up and miners' wages have been advanced, but we make bold to say that we in this district have got advances in wages which have given us as fair a share of the increase in coal prices as what has been secured by miners in any other part of the Kingdom; and this we have got without friction, trouble, or turmoil, which are so much to be avoided, in the interest of everyone, during the present national crisis."

The percentage on wages during the present quarter is to be 90 per cent.

The Press Association states that the Committee on Production have awarded all grades of railway craftsmen employed by the Midland Railway Company an advance in wages of 1s. per week on time rates and two and a half per cent. on piece rates. While the present award applies only to the Midland Railway Company, it is believed that other companies will act on the decision, and increase their craftsmen's wages by the same amount, as the claim against the Midland was considered a test case.

It is announced that the next Trade Unions Congress will be held at the Town Hall, Birmingham, on September 4 and following days. All resolutions must reach the Secretary of the Parliamentary Committee not later than June 12. No society is allowed more than three resolutions.

A meeting was held last week in the Coronation Hall, Gainford, under the auspices of the County of Durham Women's War Agricultural Committee, when Mr. F. D. Acland, M.P., said that farmers throughout England had shown a tremendously fine example by their spirit in facing difficulties. Last year was one of the most difficult agricultural seasons anybody had had to worry through, and this season threatened to be worse. The difficulties were tremendous, and they arose from the fact that they had to keep the Army at full strength and get the best possible production out of the land. They wanted to keep their armies up to a maximum strength at a time when they believed the German forces were weakening, and the farmers were loyally supporting them. The Durham farmers last year did well. They increased the acreage under wheat and oats, and also increased the quantity of their stock by 4000 cattle and 8000 sheep. That was not bad under the circumstances, and much better than some other counties in England. Referring to the work of the tribunals, he said that after May 1 there would be a closer scrutiny of certain classes of unmarried men. Farm bailiffs and foremen under thirty, and ploughmen and carters under twenty-five, would be liable to have their cases revised.

At the close of the meeting a resolution approving the action of the Board of Agriculture in endeavouring to obtain an adequate supply of labour was agreed to.

In an article in *Canadian Machinery* a statement is made to the effect that "while the average man is content to plod along, doing just what he is told to do and no more, the exceptional man, the man who is always on the look-out to improve his position, will be found not only accomplishing his allotted task with maintained effort, but will also be ready and able to offer suggestions for improving or changing existing plant equipment for the purpose of facilitating and supplementing output. It is the exceptional employee that loses no opportunity of studying the methods of the other fellow and applying them to his own work, if by so doing he can eliminate unnecessary detail and reduce the time of operation. Every young man should be alive to the rapidly-developing changes throughout the industrial field. . . ." This does not seem to agree much with trade-union principles.

OUR RAILS ABROAD.—The exports of rails from the United Kingdom continue to show a great reduction, only amounting in March to 3368 tons, as compared with 17,572 tons in March, 1915, and 40,207 tons in March, 1914.

PROGRESS OF MERCHANT SHIPBUILDING.

THERE can be no question of the vital necessity of such labour reserve as is available being utilised for the construction of merchant ships, in view of the considerable depletion of tonnage due to war risks and war requirements. That the sinking of merchant ships, either by mines or torpedoes, can have no military influence is recognised by every nation in the world except our enemies, but when it is remembered that in six weeks thirty neutral ships and nearly double that number of British ships thus disappeared, it will be seen that the situation in the future must be grave unless opportunity, when it presents itself, is taken to replace those ships with the least possible delay. Facilities have been granted to shipbuilding firms to complete half a million tons of merchant ships left standing on account of the outbreak of war. This is to the good, but more will have to be done in the near future if there is to be as early a return as possible to the normal trade conditions. During the past quarter only 69 vessels, of 80,661 tons, were launched, while 55, of 122,883 tons, were commenced; but with the great majority of ships little progress has been made. Nevertheless, these figures show that a larger number of vessels are reported as under construction than was the case at the beginning of the year. Lloyd's returns show that there are 424 vessels under construction, measuring 1,423,435 tons, whereas at the beginning of the year the number was 420 and the tonnage 1,363,590. A year ago the number was 471 and the tonnage 1,587,467. There is thus on the year a decrease of 164,000 tons, but an increase, as compared with three months ago, of 60,000 tons. Glasgow shared very largely in the increase during the three months, as did also the Tyne. In other districts the differences on either side are moderate. The figures, however, are nominal, because, unless greater progress can be made, the effect of vessels "under construction," without any merchant-ship work being done in shipbuilding yards, cannot in any way influence the oversea trading fleets or the rates of freight.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—Last Wednesday business in the pig-iron market was at a complete standstill, and although in the morning buyers offered 93s. 6d. per ton for Cleveland warrants, there were no declared sellers. In the afternoon prices dropped to 93s., but still no transactions took place. Thursday morning showed no change, the inactivity of the previous day again prevailing, while the cash buyers' price remained at 93s., and the settlement price at 93s. 6d. Alike at the afternoon session and on Friday these conditions were unaltered, sellers being disinclined to accept the 93s. quoted by buyers. Over the week, therefore, although the prices have been firmer, very little business has been done. On the resumption of business on Monday morning 1s. per ton was added to cash buyer's quotation, and 6d. per ton to cash sellers, making the price for both 94s., no alteration being recorded in the afternoon. While there were no declared sellers in the market on Tuesday morning, buyers offered 95s. per ton for Cleveland warrants, but in the afternoon there were no quotations whatever. This (Wednesday) morning buyers of Cleveland warrants added a further 6d. per ton to their offers of yesterday, but sellers were not so be tempted even with 95s. 6d., and the market closed with this as the settlement price also.

Scotch Steel Trade.—The most notable feature relating to the local steel industry during the past week has been the official regulation by the Ministry of Munitions of the price of all materials used and produced in the manufacture of steel and iron. Under no circumstances can the fixing of these prices affect the output in any disadvantageous manner, for the demand for all classes of material required for the prosecution of the war continues on a specially large scale. Indeed, in every instance makers are strenuously endeavouring, wherever at all possible, to increase the daily output on Government account, in most cases, of course, at the expense of ordinary mercantile business, which recedes further into the background as day follows day, both for home and foreign demand. Small sections, thin plates, and shell steel are most in request, and it seems almost impossible to turn these out as quickly as they are required. Although maximum prices have not yet been fixed for manufactured steel, there is every probability that an announcement may be made before very long, considering that this has already been done with pig-iron, ore, and ore freights. Boiler-plates are now quoted 14*l.* to 14*l.* 5*s.* per ton; ship-plates about 13*l.* 10*s.*; and angles, 13*l.* 5*s.* to 13*l.* 10*s.*, less the customary 2½ per cent. discount.

Malleable-Iron Trade.—After having engaged the attention of the Ministry of Munitions for some little time, a decision has at length been arrived at in connection with bar iron, the price of "Crown" bars being now officially fixed at 13*l.* 15*s.* net. Although the usual charges for delivery f.o.b., or to local centres, will still hold good, the price stated will be a maximum rate at the works, with the usual scale of extras applying to the higher grades. With the great pressure for malleable iron of all grades, notably the iron and steel bars so much in demand for Government contracts, there is a constantly increasing difficulty in overtaking the orders at present in hand, while the shortage of good puddlers prevents makers

keeping up the output as they would like. Such a very present trouble is this that in not a few instances the output is rather below the normal average than otherwise. Despite the fixing of the price for "Crown" bars for delivery in the home area, quotations under the figure already stated are fairly numerous.

Scotch Pig-Iron Trade.—The official fixing of a maximum price for pig-iron is already having a steadying effect, and now makers and consumers alike can carry on operations on a much sounder and more satisfactory basis. From the consumers' standpoint the price is fairly stiff, but naturally every branch of industry must pay toll. So far it is only the home markets which are affected by the official regulations, export prices being left free, and although but little is being put through in this direction in the meantime, values are bound to fluctuate from time to time. The home consumption of pig-iron of all grades, hematite, foundry and forge qualities, is on a very large scale. For Scotch hematite pig-iron the maximum prices fixed by the Ministry of Munitions are:—Mixed Nos. 1, 2 and 3, 8*l.* 2s. 6d. per ton net f.o.t. makers' works; special quality, containing under 0.03 of phosphorus and sulphur, 8*l.* 15s. 6d. per ton net f.o.t. makers' works; special quality, containing under 0.02 of phosphorus and sulphur, 7*l.* per ton net f.o.t. makers' works. Makers' (No. 1) iron is currently quoted at the following prices:—Calder, Summerlee and Langloan, 127s. 6d. per ton; Clyde and Gartsherrie, 130s. (all shipped at Glasgow); Eglinton, 123s., and Glengarnock, 130s. (both at Ardrossan); Dalmellington, 123s. (at Ayr); and Shotts, 127s. 6d. (at Leith), thus showing a considerable general increase in price during the present week.

Shipbuilding.—In connection with the figures given last week a regrettable error crept in; the total tonnage for the Forth during the month of March was 2563 tons, and as no launches took place either in January or February, these figures also represent the tonnage for the quarter.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—There is a remarkable keenness about the market owing to the pressure of orders for shipment and inland works before the holidays arrive, coupled with the shortage of supplies. On all sides, with the possible exception of the house-coal section, the position is becoming increasingly serious. Manufacturing fuels are scarcely to be had, and this has led large industrial concerns, chiefly those engaged on munitions, to resort to the costly expedient of converting house and best quality coals for works purposes. Best nuts are being used in the place of slacks and inferior coal, which can hardly be obtained, and the consequent rise in the coal bill of the large establishments is very heavy. The only alternative left to managements is to close down or run irregularly, and in the present critical days such a course cannot be contemplated. The demands for shipment are unusually great, but the Board of Trade Regulations are rigidly adhered to, and the tonnage going away is of an average character, with France the best customer. In certain quarters it is considered that even now the restrictions are hardly strong enough, and the large shipments are held to be responsible in some degree for the present unsatisfactory position of the home market. Gas fuels are in great request for inland works on contract account. Apart from this little business is being done, as collieries have nothing to offer. The house-coal situation is the only one which collieries and merchants are able to face with equanimity, as the falling away in the orders has given them some respite. This is due to the advent of the warm weather, and advantage is being taken of it to reduce the arrears. Coke is being consumed upon an enormous scale, and the position of users is daily becoming more difficult. Up to 34s. has been paid for best steam coke, and 24s. to 25s. for furnace quality. The general report on the situation is that with collieries working at full pressure and the railway facilities improving gradually, the outlook will speedily wear a brighter aspect. Quotations:—Best branch hand-picked, 20s. 6d. to 21s.; Barnsley best Silkstone, 17s. 6d. to 18s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house, 16s. to 17s.; best large nuts, 15s. 6d. to 16s.; small nuts, 15s. to 16s.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slacks, 12s. to 13s.; seconds, 10s. 6d. to 11s. 6d.; smalls, 8s. to 9s. per ton.

Iron and Steel.—The scarcity of materials is growing more marked, and the position is rapidly becoming acute. Makers of special steel declare that their activities are unduly restricted by the lack of supplies of tungsten, and this is more particularly felt where supplies under contracts are not sufficient to meet requirements. It was believed that the Government efforts to facilitate the supplies of ore from Australia, Burma, and the Straits Settlements, would have materialised ere now and enabled the new undertaking, run by Sheffield steel manufacturers—the High-Speed Steel Alloys, Limited—to turn out refined ore to the utmost extent of its capacity. As it is the works are not being run at full pressure owing to the shortage of the ore, and consequently this shortcoming is reflected in the quieter tone of the Sheffield special steel departments. The general trade of the city is not being conducted at such extraordinary high tension as heretofore, for manufacturers are declining large new orders until they have wiped off present arrears which accumulated in the early rushes. Works are engaged on maximum output, but many months will be required to fulfil all orders. The War Office requisitions are quite as substantial as ever, and brook no delay. Manufacturers, however, have the situation well in hand. The recent orders under this head have been for large quantities of twist-drills, files, and hack-saws. The iron and steel market is practically unchanged, and only in the case of makers of steel for munitions is there any abnormal activity. Foundry pig-iron is almost featureless, with little business to report. In the case of special qualities, however, all demands cannot be supplied. Hematites are a difficult market, and best West Coast qualities are priced at 140s., with delivery here—a rise of 4s. on the month. East Coast types also display an upward tendency, the latest quotations being 128s. 3d., delivered, as against 126s. 3d. in March. The latest markings of the various forge and foundry irons emphasise the fact that the situation in this respect is steadier than usual, for again no change is reported. Lincolnshire manufacturers are still in the happy position of finding prompt purchasers for all they are able to make. Bars and sheets are again respectively quoted at 13*l.* 10s. and 20*l.* Swedish supplies of steel and iron are not showing the advances anticipated, and prices are still very high. Colonial and overseas business remains exceedingly good. Recent mails contain orders for steel, tools, saws, sheep-shears, &c.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The great and growing scarcity of Cleveland pig-iron is causing considerable anxiety. Very little indeed is now purchasable for shipment to customers abroad, and the prohibition of exports to neutral countries, so as to allow home requirements to be fully met, is expected daily. Up to now home needs have been satisfied, but production is inadequate, and the already very low stocks are being steadily drawn upon. The export quotation for No. 3 Cleveland pig is 98s. f.o.b. No. 1 is fully 102s.; and No. 4 foundry, 97s. For home consumption, No. 3 and all descriptions below that quality stand at 82s. 6d.

Hematite Iron.—There is practically no East Coast hematite pig on the market, and most makers have disposed of all they can manufacture for the next three months. Fairly good deliveries to France continue. The export quotation for Nos. 1, 2, and 3 remains at 140s., and the price for home consumption still stands at 122s. 6d.

Shipments and Stocks of Pig-Iron.—Under the conditions prevailing, shipments of pig-iron from the port of Middlesbrough cannot be regarded as unsatisfactory. To date this month they amount to 18,821 tons, as compared with 19,415 tons to the same date last month, and 3985 tons for the corresponding part of April a year ago. Practically the only stock of pig-iron left is the 45,920 tons of Cleveland in the public warrant stores. Of this, 44,013 tons are No. 3, and 1907 tons other qualities deliverable as standard. Since the beginning of the month 10,919 tons of No. 3 and 471 tons of standard iron, making a total of 11,390 tons, have been taken from the stores. The stock is thus being reduced at the rate of some 1200 tons per working day.

Coke.—Demand for coke for local use keeps good, and further business is reported at the arranged maximums for home consumption of 28s. at the ovens for medium blast-furnace sorts, and up to 30s. 6d. at the ovens for qualities low in phosphorus.

Foreign Ore.—There is not much business passing in foreign ore, but deliveries on contracts keep good. The position is peculiar. The action of the Government has brought down freights, and in the ordinary way in the open market steamers Bilbao-Middlesbrough can now be fixed at 23s., which makes the ex-ship Tees price of 50 per cent. Rubio round about 40s., but consumers buying to manufacture iron for home use have the advantage of arranging Bilbao-Middlesbrough freight through the Government at 17s., which makes the ex-ship Tees price of best Rubio 34s. The f.o.b. quotation at port of despatch, for 50 per cent. Rubio is 17s. Imports of foreign ore to the Tees to date this month amount to 87,959 tons.

Ironstone Miners' Wages.—At a meeting of the Cleveland ironstone mineowners and representatives of the miners, held at Middlesbrough this week, Sir Hugh Bell, Bart., presiding, Mr. H. Dack, on behalf of the men, drew attention to the increased selling price of pig-iron, and said that the miners felt they were entitled to a higher advance than that which accrued under the scale. He asked for an advance of 10 per cent. The chairman pointed out that, according to the formula which had been adopted for a long time past, the recent ascertainment entitled the men to an advance of 6.10 per cent., which would raise wages to 58.10 per cent. above the standard. Mr. Dack intimated that he would have to consult the men in the district before effecting a settlement on the question, and consequently a further meeting of the mineowners and miners' representatives was arranged for the 27th inst.

Manufactured Iron and Steel.—Manufacturers of finished iron and steel keep busily employed, almost entirely on Government work, with the result that the numerous ordinary commercial inquiries in the market are still neglected. Certain descriptions of manufactured iron have been advanced and usual discounts discontinued. Advances in other material is anticipated. At present principal market quotations may be put at:—Common iron bars, 13*l.* 15s.; best bars, 14*l.* 2s. 6d.; double best bars, 14*l.* 10s.; treble best bars, 14*l.* 17s. 6d.; packing iron (parallel), 10*l.*; packing iron (tapered), 11*l.* 10s.; iron ship-plates, 11*l.* 10s.; iron ship-angles, 13*l.* 15s.; iron ship-rivets (⅞-in. diameter), 16*l.* 10s.; iron ship-rivets (⅝-in. diameter), 17*l.* 10s.; steel bars (no test), 14*l.*; steel ship-plates, 11*l.* 10s.; steel ship-angles, 11*l.* 2s. 6d.; steel joists, 11*l.* 2s. 6d.; steel strip, 15*l.*; steel hoops, 15*l.* 10s.; and heavy steel rails, 10*l.* 17s. 6d.—rails net f.o.b.; and steel joists, ship-plates, ship-angles, and iron bars net at works, and other descriptions less the usual discount.

NOTES FROM THE SOUTH-WEST.

Cardiff.—There has been no abatement of the pressure for all classes of large and small steam coal, with a large number of vessels in dock and supplies coming down from the collieries very slowly, there is little prospect of early relief; but it was reported on Saturday that in view of the record prices now current, the authorities were refusing to grant export licences. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have made 42s. to 43s. per ton; Monmouthshire black veins, 42s. to 43s.; Western Valleys, 42s. to 42s. 6d.; Eastern Valleys, 39s. to 42s.; best bunker smalls, 23s. to 24s.; and cargo smalls, 16s. to 19s. per ton. Annexed are quotations for bituminous descriptions:—Best households at pits, 23s. to 24s.; No. 3 Rhondda large, 40s. to 42s.; No. 3 smalls, 23s. to 24s.; No. 2 Rhondda large, 33s. to 34s.; No. 2 smalls, 18s. to 20s. per ton. The latest quotation for patent fuel has been 40s. to 42s. per ton. Special foundry coke for export has made 37s. 6d. to 42s. 6d.; good foundry coke, 32s. 6d. to 37s. 6d.; and furnace coke, 42s. 6d. to 47s. 6d. per ton. As regards iron ore, Rubio has brought 39s. to 40s. per ton, upon a basis of 50 per cent. of iron, and charges, including freight, insurance, &c., to Cardiff or Newport.

Western Trade Matters.—Freight rates for the Mediterranean, South America, and Bay ports have given way a little, but for north French ports higher terms than ever have been secured.—Siemens tin-plate bars have made 13*l.* to 13*l.* 5s. per ton at Swansea; these were considered record prices.—The Town Line (London), Limited, has declared a further interim dividend of 5s. per share; this is the third interim distribution for the financial year ending June 30.—The directors of the Cynon Colliery Company, Limited, recommend an interim dividend of 7½ per cent., less tax, payable April 15; the corresponding interim distribution a year since was 5 per cent.—The directors of the Ocean Coal and Wilsons, Limited, report that the profits available for distribution for 1915 amount to 302,654*l.*; a dividend of 10 per cent. is proposed on the ordinary shares, free of income tax, making 16 per cent. for the year; a similar rate of dividend was maintained for the previous three years.—Mr. R. Williamson, who has for many years held the post of general manager of the Mountstuart Dry Docks, Limited, has been elected to a seat on the board to fill a vacancy occasioned by the death of Mr. E. Gunn.—The Mold and Denbigh Junction Railway Company gives the holders of its "B" debenture stock a dividend of 3½ per cent. for 1915; the corresponding dividend for 1914 was at the rate of 3 per cent.; judgment has been given in favour of the London and North-Western Railway Company with reference to the construction of a working agreement; an appeal against this judgment has, however, been lodged on the advice of counsel.

Steam Coal.—All descriptions of Monmouthshire steam-coal are so fully booked that colliery owners are in most cases refusing further orders; sellers of small parcels for April loading have been practically able to command their own terms.

Tin-Plates.—During the next few weeks the tin-plate trade will be subjected to the process of dispensing with every available single man who can be spared for the Colours; this will put an end to short shifts, and will tend further to reduce the number of mills in operation. It is considered that the pooling system introduced a few years ago, and regulated by periodical conferences at Swansea, is proving beneficial to the trade, as by its operation prices have been kept steady, while orders have been placed so that all works have benefited more or less from them.

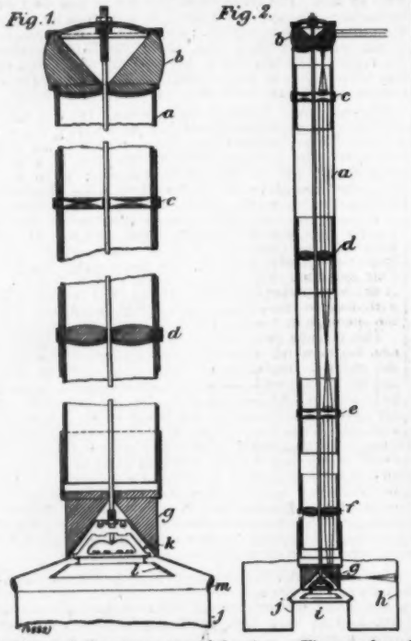
PRESS FOR BALING LIGHT STEEL SCRAP.—An illustrated description is given in the *Iron Age* of a new baling press built by the Standard Pressed Steel Company, of Ohio, Cleveland, for dealing with light and bulky scrap. The charging-box is 16 in. wide, 26 in. deep, and 42 in. long. In this, the material is compressed into a bundle slightly under 16 in. square, a size suitable for charging in open-hearth furnaces, and it weighs from 150 lb. to 400 lb., depending upon the kind of material. The working of the press requires about 10 horse-power. It occupies a floor space of 7 ft. by 14 ft. and develops about 14,000 lb.

OXYGEN AND HYDROGEN FOR SHIPBUILDING YARDS.—The National Ox-Hydric Company, of Chicago, have installed one of their electrolyser batteries for supplying 5000 cub. ft. of oxygen and twice as much hydrogen per 24 hours in the yards of the Fore River Shipbuilding Corporation at Quincy, Mass., United States. The plant, which is supervised by one attendant, comprises, says *Metallurgical and Chemical Engineering* of March 1, a 75-horse-power crude-oil engine driving a 75-kw. generator, the battery, gas-holders, compressors, &c. The cells are of the usual filter-press type, the electrodes, which are corrugated and heavily coated with nickel, being separated by rubber-bound asbestos diaphragms. The material of the electrodes (described as a special alloy), and the way in which the conduits are kept free of electrolyte (caustic potash of 21 per cent.) are not explained. Concussion tanks are interposed between the compressors and pipe-lines to take up the pulsation of the compressors.

THE PARODI PERISCOPE.

WE illustrate in Figs. 1 and 2, reproduced from the *Rivista Marittima*, the periscope recently patented by Professor Parodi. In this periscope, the Italian review states, no essential novelty is introduced from the optical point of view, except that a larger use is made of lenses of toroidal section. At the top of the optical tube *a*, which rises from the submarine, is fitted a total reflection toroidal prism *b*, arranged so as to form both an achromatic converging lens and a total reflection prism, the curves of the various faces being determined so as to secure this result. The rays from the toroidal prism *b* first pass through a pair of plano-convex condensers *c*, which produce a parallel beam extending to a converging lens, toroidal in shape, which is added as shown at *d*. The image reflected by the toroidal prism passes to the lower end of the tube through the two plano-convex condensers *e* and a converging lens marked *f*.

A total-reflection toro-prismatic system, *g*, is fitted at the lower end of the optical tube, having its conical reflecting surface at right angles to the corresponding



surface of the upper toroidal prism. The novelty of the Parodi device is that the luminous rays from the horizon are so deviated that the image of the objects is given on a cylindrical screen *h* placed round the lower prism, as shown in Fig. 2. The screen reproduces the whole horizon visible to the observer placed at *i*, and who views it through the cylindrical glass screen *j*. The image can be enlarged. The conditions of an observer who views the horizon direct are thus exactly reproduced, there being added the possibility of directing from the screen the principal problems relating to the course of the boat by combining the picture with a fixed index and the indications of a compass which are projected on the screen *h*, as shown in Fig. 2.

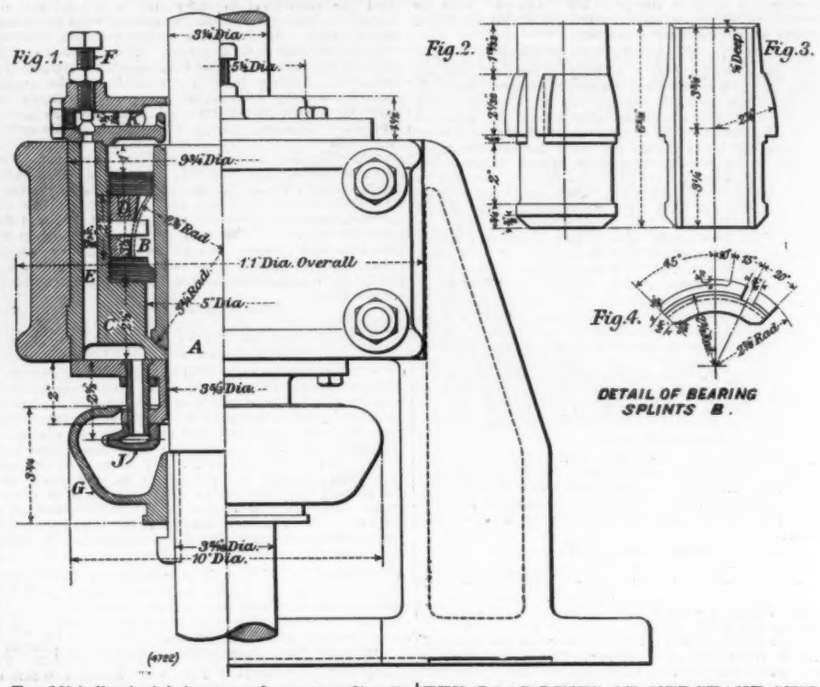
The compass, marked *k* in Fig. 1, has a transparent card, and is fitted in the conical cavity of the lower prism; it is lighted from the top, and there is thus projected on the screen the entire graduation of the card through the conical mirror *l* and the annular lens marked *m*. The apparatus is destined to act as a "perigraph," but it can act also as a periscope by simply placing in front of the lower prism *g* a simple and supplementary rotary ocular device.

The Italian journal from which we quote cannot vouch for Professor Parodi's "oloperigraph" being found in everyday practice so simple and perfect as it appears at first glance. It believes that the great difficulty will be a lack of light for a clear direct sight; in regard to this it should be noted that the images are projected inside a kind of dark chamber, cylindrical in shape, limited by the screen, and are thus viewed under very favourable conditions.

STEEL PRODUCTION OF AUSTRIA-HUNGARY, 1915.—The aggregate production of steel in Austria-Hungary and Bosnia during last year was as under:—

	Tons
Austrian works	1,978,802
Hungarian ,, ...	688,267
Bosnian ,, ...	19,157
	2,686,226

MICHELL JOURNAL BEARING.



THE Michell principle has proved so extraordinarily successful as applied to thrust-blocks that there has naturally been a strong inducement to extend its application to ordinary journal bearings. The bearing which is illustrated in Figs. 1 and 4, above, shows a very interesting instance of this further development of the Michell principle. The bearing represented has been applied to two circulating pumps at the Newport Power-Station, Melbourne, Australia. These pumps were made by the G. Weymouth Proprietary, Limited, of Melbourne, and are of 220 horse-power, the shaft speed being 490 revolutions per minute.

As will be seen from Fig. 1, the shafts are vertical, and, as is well known, satisfactory lubrication is in such case a matter of some difficulty owing to the tendency of the oil to run out at the bottom. In the bearings illustrated, however, this difficulty is completely overcome. There is a definite oil circulation, which is maintained by the rotation of the shaft, and leakage of oil entirely prevented. The journals have, we are informed, been running with great satisfaction for some months.

Referring to our illustrations, it will be seen that the shaft A is surrounded by four splints or brasses B, the design of which is shown in detail in Figs. 2 and 4. The ribs or projections shown on the back of these splints are turned to a spherical surface, but, as indicated in Fig. 4, this surface is cut away one-sixteenth clear on the side of the leading edge of the splint, so that when in position the brass can tilt a little to facilitate the entrance of oil between the lubricated surfaces. The lower ends of the splints are also turned to a special surface struck from the same centre as that to which the ribs are turned. The splints rest by these spherical surfaces on the housing C of the bearing. A hollow cone D is screwed down on to the ribs of the splints, holding them in position as indicated. By screwing this cone up or down, the oil clearances between the brass and journal surfaces can be adjusted. It will be seen that by this arrangement the bearing is set up towards the centre of the shaft from four directions, instead of from two, as with ordinary two-part brasses.

The lubricating oil draining from the bearing falls into the cup G, which is keyed to the revolving shaft. Dipping into this cup is a nozzle J, and the oil carried round by the rotation of the cup rushes up this nozzle and through the passage E to the top of the bearing, whence it is distributed through the port K. The amount of oil pumped can be controlled by screwing up or down the set-screw shown at F. A continuous circulation of oil between the rubbing surfaces is thus secured.

Mr. Michell's representative in this country is Mr. H. T. Newbigin, A.M.I.C.E., 3, St. Nicholas Buildings, Newcastle-on-Tyne, to whom we are indebted for the foregoing particulars.

THE LOAD-LINES OF MERCHANT SHIPS: WORK OF THE LOAD-LINE COMMITTEE (1915).*

By SIR PHILIP WATTS, K.C.B., F.R.S., LL.D., D.Sc., Hon. Vice-President.

THE question of the maximum depth to which vessels should be loaded is one which is of continual interest and importance to shipping and commercial communities. In past times many attempts have been made to regulate the depth of loading by means of more or less fixed rules, and when a comparatively uniform type of sailing vessel was all that had to be provided for, the application of such rules was simple and the results obtained fairly satisfactory. But with the introduction of steam power and the development of different types of ships, the problem of framing general rules which would prevent overloading without undue interference with trade became so difficult that for many years it was held by many to be incapable of a satisfactory solution. But, slowly, by patient investigation and the collation of data based on actual sea experience, agreement was reached on certain fundamental principles which found expression in the report of the first Load-Line Committee in 1885.

At various stages in the history of the subject, valuable papers have been read at our meetings, and now that the report of the latest Load-Line Committee, of which I had the honour to be chairman, has been issued, it is but fitting that we should again consider the question in the light of that report, which in some respects marks a new departure in dealing with the subject.

It is desirable in the first place to glance at the history of the assigning of freeboard and the marking of load-lines, in order to understand the successive steps which have been taken, and rightly to appreciate the new report on this subject.

The first record of a load draught of water assigned as the practical limits consistent with safety was made in Lloyd's Register Book in 1774, but how this draught was calculated is not known. The record was, however, maintained for 60 years. Early in the last century the rule for freeboard in merchant vessels was from 2 in. to 3 in. per foot of depth of hold. Underwriters are so deeply interested in the loading of vessels that it is not surprising to find that what was, perhaps, the first attempt to regulate the depth of loading by a fixed rule was due to them. The Committee of Lloyd's proposed about the year 1835 that a freeboard of 3 in. per foot of depth of hold should be taken as a guide of safe loading; this became known as "Lloyd's Rule," and was widely used. Such a rule did not, of course, permit of that discrimination between different types of ship which to-day is regarded as essential.

A more serious attempt to regulate the loading was that made by the Liverpool underwriters about the same time. It also was based on a rule of so many inches per foot of depth of hold; but, unlike "Lloyd's Rule," it varied according to the size of the vessel from 2½ in. per foot depth of hold for vessels of from 10 ft. to 12 ft. in depth, to from 3½ in. to 4 in. for vessels of from 24 ft. to 26 ft. in depth. And, moreover, in applying the rule,

* Paper read at the Institution of Naval Architects, April 12, 1916.

regard was had to most of the features and conditions considered in modern practice, such as age and class, dimensions, superstructures, sheer, and season of the year. Under this rule the larger vessels were not permitted to load nearly so deeply as in later practice.

It should be mentioned that the old system of tonnage measurement known as "Builders' Measurement" caused the forms and proportions of cargo-ships to approximate to a uniform type, in which the length was about 3½ times the breadth, and the depth about three-quarters of the breadth, and to this class of vessel the application of the simple rule of so many inches of freeboard per foot of depth of hold appears to have given fairly satisfactory results. The adoption, however, of Moorsom's system of tonnage measurement in the Merchant Shipping Act, 1854, removed the inducements to build vessels of this type, and cargo ships soon began to vary materially in proportions according to the trades in which they were to be employed.

With diversity of type, the depth of loading could no longer be regulated by any simple rule of freeboard, and it became necessary, in order to arrive at correct results, to give careful consideration to the special characteristics of each type, including differences in construction and superstructures.

In various quarters the loading of these new ships attracted considerable attention, and, as might have been expected, there was a great diversity of opinion as to the proper depth to which they should be loaded. The London Salvage Association called the attention of owners and masters to cases in which vessels were loaded deeper than 3 in. of freeboard per foot depth of hold. Vessels carrying Government stores were required to confine their loading to this rule. Emigrant ships were allowed to have a freeboard equal to only one-third of their draught of water, while vessels carrying troops were required to load to a scale of 3½ in. to 4 in. per foot depth of hold.

Questions of freeboard frequently arose in one way and another, but no definite proposal appears to have been made until 1867, when the Institution of Naval Architects forwarded to the Board of Trade a report respecting the construction, equipment, and freeboard of ships, which was presented to Parliament in 1870.

As regards freeboard, the Institution strongly recommended in the following terms that a certain minimum of freeboard should be required:—

"There is a minimum height of freeboard which cannot be safely reduced in sea-going ships of ordinary fitment, and it is desirable to fix this minimum height. Freeboard should be understood to be the vertical height of the upper surface of the upper deck (not spar deck) at the side, amidships, above the load-water line. The proportion of freeboard should increase with the length. One-eighth of the beam is a minimum freeboard for ordinary sea-going ships of not more than five breadths to the length, and $\frac{1}{12}$ of the beam should further be added to the freeboard for each additional breadth in the length of the ship; this would give:—For a ship of 32 ft. beam and 160 ft. long, 4 ft. freeboard. For a length of 192 ft., 5 ft. freeboard. For a length of 224 ft., 6 ft. freeboard. For a length of 256 ft., 7 ft. freeboard, the beam remaining the same; but, as the addition of a spar-deck on long vessels may be considered an equivalent or substitute for the increased freeboard required for extra length, a complete spar-deck would leave the freeboard of these extra lengths at the original height of 4 ft.

"It is not considered desirable to offer any recommendations with regard to poops and forecastles. It must depend entirely upon the professional judgment of the designer of a ship whether, looking to her proportions, form, and purpose, the additions of poop and forecastle are expedient and safe. In general, where poops and forecastles are adopted they should be closed and seaworthy, but their weight may be inexpedient in long, fine ships, and there are cases where a light top-gallant forecastle (*i.e.*, an open forecastle raised above the level of the upper deck) may be useful in keeping heavy seas out of the ship. In general, spar-decks in long ships are preferable to poop and forecastle, and no diminution of freeboard should be allowed for a poop or forecastle."

In 1870 what was known as the spar-decked vessel was introduced, with lighter scantlings in the upper or spar-deck portion; and as the seaworthiness of these vessels was greatly influenced by the depth to which they were loaded, Lloyd's Register found it necessary to insist on a minimum freeboard, measured from the main or middle-deck stringer-plate to the water-line, of 1½ in. for every foot of depth of hold, from the top of the floor-plates to the upper side of main or middle-deck beam. In the following year, however, spar-decked vessels began to be built with much stronger upper works, and this restriction was accordingly withdrawn.

In this year (1871) a Merchant Shipping Act was passed, in which provision was made for the marking of a scale of feet showing the draught of water at the stem and stern-post of vessels, and the Board of Trade were empowered to appoint persons to record the draught of water of all sea-going ships, as shown by this scale of feet when leaving port.

About 1873 awning-decked vessels came into existence, having a continuous deck constructed above the main deck of much lighter scantlings than the main portion of the hull; and to prevent the overloading of these vessels, Lloyd's Register made their classification conditional on a maximum load-line being fixed and marked on the sides of the vessels. This was the first instance of the marking of a fixed load-line being required by any public body, and the marking adopted was a diamond with a bar at each end, and the letters "L" and "R" (meaning Lloyd's Register) above the bars.

In the meantime the famous Plimsoll agitation had been going on. In 1873 the Government appointed the Royal Commission on Unseaworthy Ships, and one of the questions brought under its consideration was the "load-line." In their final report, issued in 1874, the Commissioners said that they could not prescribe any universal rule for the safe loading of all merchant ships, and that an Act of Parliament enforcing any scale of freeboard would be mischievous. They recommended, however, that "every merchantman should have marked on each of her sides, amidships, a vertical scale of feet downwards from the edge of her main deck," and that "a note of this reading should be entered in the log-book after the vessel has received her full load, immediately before the time of her starting on her voyage, and should, wherever practicable, be left with the officer of Customs, or with the British Consul, by whom it should be recorded."

While the Commission was sitting Parliament passed the Merchant Shipping Act, 1873, which enacted that the amount of clear side and draught of water which a vessel had at the time of leaving port should be recorded, and provided for the detention by the Board of Trade of overladen and improperly-laden vessels. Then followed the Merchant Shipping Act, 1875, which contained provisions regarding the loading of ships that have remained in force till the present time. The position of the deck-line was to be marked on the sides of all ships, and the owners of foreign-going vessels were required to mark a circular disc on the sides of their ships, showing the maximum draught to which they claimed to load, to record the distance between the centre of the disc and the deck-line before clearing at the Custom House, and to insert this record in the agreement with the crew. This Act was only to remain in force one year, and accordingly, in 1876, a larger Act was passed, in which these requirements were confirmed, and the compulsory mark of the disc extended to include all British vessels, except those under 80 tons register, engaged exclusively in the coasting trade, fishing-boats, and pleasure yachts.

It must be borne in mind that, although the disc mentioned above was a mark required by Statute to be affixed by the shipowner on the sides of his vessel, its position was determined by the owner entirely at his own discretion, and it only represented the draught of water to which he might, without breaking the law, load his ship. It might be, and often was, placed in a position to which the owner never intended to load his ship. Possibly it was sometimes placed in a position to which the vessel could not be loaded without serious risk.

The power to detain overladen ships was given to the Board of Trade in the Merchant Shipping Act, 1873; but in attempting to use this power the need for certain well-defined rules for the guidance of the surveyors soon manifested itself, and the Board of Trade found it necessary to obtain assistance in formulating such rules. They accordingly arranged a conference in 1875 between their own officers and representatives of Lloyd's Register and the Liverpool Underwriters' Registry for Iron Vessels to consider the matter. The conference broke up without coming to definite conclusions on some of the points it had had under consideration; but it carried resolutions embodying recognised fundamental principles necessary to be considered in dealing with the load-line question, such as the following:—

(1) The construction and strength of the ship as a whole. (2) The ratio of the enclosed space above the water-line to the space below it. (3) The form and proportions of the ship, her sheer, and the strength and scantling of her deck fittings. (4) It assumed the ship to be a strong, well-built, flush main-decked ship of average proportions, properly stowed, fit to carry dry and perishable cargoes to and from all parts of the world under all circumstances of wind and weather. (5) That freeboard is height of platform above water-line. (6) That in the larger class of ships and steamers height of platform is of importance, whatever may be the spare buoyancy of the ship.

In 1882 the Board of Trade, in order to give some guidance to their surveyors, prepared Tables of Freeboard, which were given to them for general information, but not as final decisions of the Board of Trade. These tables did not command universal approval, and, in the circumstances, the Board of Trade appointed in December, 1883, the first Load-Line Committee to deal with this important subject. This Committee was thoroughly representative of the interests concerned, and carried out complete investigations of the various questions involved. They reported in August, 1885, that it was practicable to frame general rules concerning freeboard which would prevent overloading without unduly interfering with trade, and submitted tables, which had been in the main prepared by Lloyd's Register, giving the maximum loading which could be permitted in cargo-carrying vessels.

These tables were adopted by the Board of Trade, and on the voluntary application of owners the Board of Trade and Lloyd's Register assigned load-lines to vessels in accordance with them. For nearly five years this condition of things continued, but there was no statutory obligation requiring shipowners to have their vessels marked with load-lines in accordance with the tables. The working of the tables was, however, generally acceptable, and at the end of this period—in 1890—the Merchant Shipping (Load-Line) Act was passed, making it compulsory for the load-line disc to be fixed in accordance with these tables. Provision was made in the Act enabling the Board of Trade to appoint authorities to assign load-lines to vessels on their behalf, and to modify the Tables of Freeboard from time to time as might be found necessary. The Board appointed Lloyd's Register, the Bureau Veritas, and the British Corporation for the Survey and Registry of Shipping to assign freeboards to vessels on their behalf, and from time to time they have modified the Tables of Freeboard in conjunction with these bodies. To complete this review of the position before the appointment of the Committee over which I have presided, I should refer to the modifications made in the Tables of Freeboard since the passing of the Act in 1890.

These modifications were in some cases necessary on account of the evolution of new types of vessels, and in others simply on account of experience gained in applying the rules. The principal modifications were made in 1898 and in 1906. In the former year a Committee was appointed for dealing with the questions involved, and, on its recommendation, the Board of Trade modified the Tables of Freeboard with regard to the Winter North Atlantic Freeboard, made provision for larger vessels than those previously provided for, and for so-called turret-deck vessels.

It was, however, recognised that the tables needed more complete revision. They had been modified and added to since 1885, as the first Load-Line Committee anticipated would be necessary, but apparently sufficient care had not been taken to obtain and maintain that clearness in arrangement so desirable in dealing with this complicated subject—the assignment of freeboards to all kinds and conditions of ships. Moreover, it was doubtful whether the tables were fair and just to vessels of types different from those in existence when they were framed. It was therefore inevitable that a substantial revision should be made, especially when it was found that other maritime nations were considering the question of compulsory load-lines. When, therefore, the German Tables of Freeboard, based upon the British rules, were issued in 1903, the movement towards revision took definite shape, and the various authorities entrusted with the duty of assigning freeboards to vessels set to work. On their recommendation the Board of Trade, in 1906, revised the Tables of Freeboard, which had been in use for over twenty years.

The general effect of this revision was to allow vessels having superstructures which cover more than half the vessel's length, and which comply with more stringent requirements as to strength and seaworthiness than those previously laid down in the old tables, to load somewhat more deeply than was permitted under their old tables. This reduction of freeboard was considered safe in view of the large proportion of the length of the vessels covered with deck erections, and of the efficient means for closing the openings in weather-decks.

This revision gave rise to the agitation of a few years ago, during which statements were made to the effect that the reduced freeboards permitted by the revised rules had led to increased losses of ships and men. It is possible that, in part, at any rate, this agitation led to the appointment of the latest Load-Line Committee in 1913. The main reason for the appointment of the Committee was, however, the fact that so many maritime Powers had followed the lead of Great Britain, and made the marking of load-lines compulsory, that it was very desirable to formulate a set of rules which could be adopted as international rules. The advantages of an international load-line to the shipping and commercial interests of the world are obvious, and the principal maritime Powers accepted an invitation to an International Conference on Load-Line, to be held in London. If it had not been for the war, that conference could have been held some months ago.

In concluding this review of the history of the load-line question, I cannot help remarking on the gradual growth of the rules and regulations on the subject. Whatever may be said about hasty and ill-considered legislation on some matters, it must be acknowledged that on this question of the load-line the utmost deliberation has been shown, and the various changes have succeeded one another at considerable intervals, and as the result of mature experience.

The Constitution of the Committee.

The reference to the Load-Line Committee appointed in April, 1913, was to advise the Board of Trade as to the attitude to be adopted by the British representatives at the International Conference, and for that purpose to consider in what respects, if any, the existing Tables of Freeboard required further revision in the light of the experience gained since the revision made in 1906. The work of the Committee was therefore of a twofold nature—viz., the preparation of rules suitable for international acceptance, and an investigation of the basis on which such rules should be formulated. It was implied in the reference that the working basis should be the then existing Tables of Freeboard which had already been generally accepted by the principal maritime Powers.

The first duty of the Committee was, therefore, to determine whether there was any evidence which made it necessary or desirable to depart from the freeboards assigned under the existing tables, and for that purpose evidence from every possible source was obtained and considered. There were three main sources of information:—

(*a*) The records of shipping casualties both as regards losses of ships and men; (*b*) the personal experiences of the behaviour of vessels at sea; (*c*) the experience of the various assigning authorities.

Taking the casualties to steamers from all causes for the twenty years ended June 30, 1913, it was found that the average annual percentage of loss had fallen from 2.01 for the first five years of that period to 1.38 for the last five years. For freeboard purposes, however, the casualties classed as "foundered" or "missing" are the most important, and statistics relating to these causes were compared for the seven years prior to the revision of the Tables of Freeboard in 1906, and for the seven years subsequent to that revision. This comparison showed that the average annual percentage of loss for the first period of seven years was 0.30, and for the second period 0.27. Another inquiry of the same kind showed

that the annual percentage number of men washed overboard and drowned from steamers had diminished since the revision of the tables. Further, each case of a foundered or missing vessel which occurred in the period of fourteen years under consideration was examined in detail, and abstracts were prepared on various bases, such as cause, or probable cause, of loss, age, size, and nature of cargo. The several cases were divided into two classes: those in which the freeboard was unaltered after the revision of 1906, and those in which the freeboard was altered under the revised regulations. Beyond this brief summary, I do not think that it is necessary to recapitulate in detail the various inquiries that were made in order to investigate the general sufficiency of the freeboards assigned under the existing rules.

The Committee found that there was no evidence to indicate that freeboard was a dominant factor in causing the losses, and that the revision of the Tables of Freeboard in 1906 cannot be regarded as having caused an increase in such losses. They also came to the conclusion that, on the whole, the freeboard allowed by the revised tables, as now in use, is quite sufficient to ensure the safety of vessels, although in some cases vessels are less comfortable, owing to a greater liability to ship water on the weather-decks.

In view of such conclusions it was obvious that the existing Tables of Freeboard would form a good basis for any rules which could be put forward as suitable for international acceptance. The Committee therefore entered upon their second duty of the preparation of new rules, and in view of the object to be attained—viz., that of international agreement—they considered it necessary to review the whole subject anew. Since it is obvious that a vessel must not be loaded so deeply that she will be rendered unsafe, either through insufficient reserve of buoyancy, quite apart from strength, or through insufficient strength, quite apart from reserve of buoyancy, the question of freeboard allowance may be divided into two distinct parts:—(*a*) The amount of freeboard which can be safely assigned under the assumption that the structure of the vessel is sufficiently strong; (*b*) the standard of strength which should be required in order that a desired freeboard may be allowed.

For convenience it is desirable to differentiate between what may be called the "geometric freeboard"—that based solely upon the dimensions and form of the vessel—and the freeboard determined by considerations of strength, so as to ensure that the vessel would not be so stressed as to overtax her strength. The standard of strength hitherto required has been different in various countries—*e.g.*, the British standard is the printed rules of Lloyd's Register of Shipping for the year 1885; the French standard is the current rules of the Bureau Veritas; while the German standard is the current rules of the Germanischer Lloyd.

Although it would have been possible to adopt, more or less, the existing procedure respecting the assignment of the geometric freeboard to international requirements, there was considerable difficulty in the formulation of a standard of strength which would be acceptable for international freeboard purposes. It was necessary for the Committee to break new ground in this direction, and a sub-committee was appointed to deal with the matter. The work of the sub-committee was of great interest and importance. So far as strength is concerned, the work is separately considered in a paper to be read to us to-day by Mr. W. S. Abell, the chairman of the sub-committee, and I shall only refer to the broad principles involved.

The two main divisions of the subject of strength in relation to freeboard deal with longitudinal strength and with transverse strength. As regards the former, the following conditions were taken account of:—(1) Stiffness, or the ratio of the length of the vessel to the depth of the vessel up to her strength deck; (2) the resistance to bending defined as a longitudinal modulus of resistance; (3) the capacity of the vertical plating to resist the shearing forces, which capacity is measured by the thickness of side plating; and (4) the possible failure of the side plating by secondary bending, due to insufficient support, which involves the relation between the thickness of side plating and the spacing of the transverse frames.

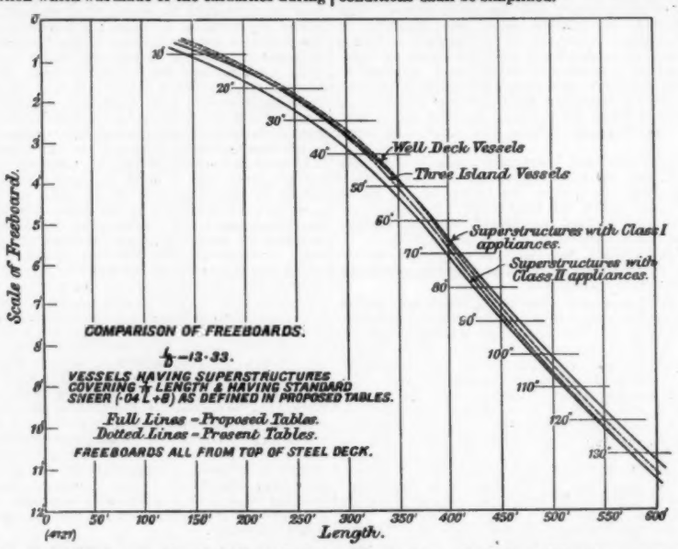
The question of transverse strength was considered so far as the information available admitted. Consideration was given to typical ships of various lengths and of various ratios of length of vessel to the depth of vessel up to strength deck. All these typical vessels were assumed to have what is very common—viz., a beam of 10 ft., plus one-tenth of the length of the vessel. Two leading types were considered—viz. (1) the flush-deck vessel and (2) the complete-superstructure vessel.

Detailed rules framed on the results of these investigations were formulated, and appear in Appendix II. to the report.

At the present time the assigning authorities have rules under which, if a vessel has not the full scantlings set out in their tables corresponcing to the dimensions of the vessel, she is compelled to accept a higher assignment of freeboard than if she had those full scantlings. Many vessels engaged in carrying goods of a bulky and light character, in which internal capacity rather than deadweight capacity is the main object of the design, have freeboards and scantlings arranged on this basis, and this is more particularly the case when such vessels have to trade to ports where the depth of water available is limited. The rules now formulated deal with this matter more clearly and conveniently than those hitherto in use. As regards strength, the present rules deal mainly with longitudinal strength. The proposed rules take account of transverse strength in a manner more conveniently admitting of quantitative application to the assignment of freeboard.

I may mention, as a matter of historical interest, that on account of the greater spacing of transverse framing adopted in His Majesty's ships than is usually the case in merchant ships, the question of the stiffness of the skin-plating in relation to resistance to buckling has always been the subject of close investigation at the Admiralty. A notable instance occurred in the case of H.M. ships Colossus and Edinburgh, laid down in 1879 and launched in 1882. These were the last two vessels built on the general design of His Majesty's central citadel turret ship Inflexible, and were the first battleships in H.M. Navy built with steel bottoms. The reduction in thickness of the bottom plating, resulting from the change from iron to steel, associated with the same spacing of transverse frames as in the iron-bottomed ships, necessitated very careful consideration to ensure that no failure should occur by the buckling of the plating, even though the plating, apart from buckling, might be adequate to resist all longitudinal stresses.

Returning to the geometric freeboard, it will be remembered by all interested in this question that the ordinary assignment of freeboard, as at present made, takes no account of internal water-tight subdivision. The Tables of Freeboard have as their basis an approximation to the reserve of buoyancy possessed by the vessel. It was therefore apparent to the Committee that some regulations were necessary in respect of the protection of the various vulnerable openings in the weather-decks and sides of the vessel and in the different classes of superstructure for which a freeboard allowance was given. The examination which was made of the casualties during


Scale of Freeboard.
Well Deck Vessels
Three Island Vessels
Superstructures with Class I appliances.
Superstructures with Class II appliances.
COMPARISON OF FREEBOARDS.
1/D = 13·33.
VESSELS HAVING SUPERSTRUCTURES COVERING ¼ LENGTH & HAVING STANDARD SHEER (·04 L+8) AS DEFINED IN PROPOSED TABLES.
Full Lines = Proposed Tables.
Dotted Lines = Present Tables.
FREEBOARDS ALL FROM TOP OF STEEL DECK.
Length.

the fourteen years already mentioned indicated that some 20 per cent. of the vessels which foundered during the period referred to were lost owing to the entry of water through hatchways and ventilators.

As a result of these considerations, it was decided that a separate section of the rules should be set apart to deal with this phase of the subject, and should relate to the proper closing of machinery casings, openings in weather-decks and sides of vessels, freeing ports, access to various spaces, and the safety of the crew. These particular regulations were named "Conditions of Assignment of Freeboard." Compliance with them does not affect in any way the main construction of the vessel, and can be made at little expense. It was not considered reasonable to recommend a small addition in freeboard as compensation for a known weakness in, say, the support to hatch-covers, as such weakness might prove dangerous, or perhaps fatal, even if associated with a considerable increase of freeboard. The Committee felt strongly the need for these "Conditions of Assignment," and they have recommended that these requirements might, with advantage, be adopted for British practice in the immediate future. For new vessels very little alteration or addition would be required.

In the course of the examination of the various details relating to the present assignment of freeboard, certain defects or inequalities of treatment have presented themselves. These differences may be divided into two main parts. The present rules allow very low freeboards to be assigned to small flush-deck vessels. Although it is certainly true that there are very few steamers of this class, yet it was ascertained that in many fishing vessels the actual freeboards found necessary by sea experience were much in excess of that minimum which an assigning authority would be required to accept. As the Tables of Freeboard are minimum requirements, and as the effect of legislation and commercial competition is to tend to compel every one in process of time to work to minimum requirements, it was deemed desirable to increase the tabular requirements for small flush-deck ships. This modification does not in general affect vessels of about 250 ft. in length and above. The existing rules allow of preferential treatment to some extent for particular types of vessels, while there are also anomalies in the rules regarding the allowances for superstructures in respect of the closing of openings in bulkheads by appliances of a portable and temporary character. The Committee considered it desirable for international purposes to remove such inequalities and to modify the procedure in order to obtain equitable treatment. Apart from this there were several points which, although not of major importance, yet with advantage could be redefined or restated in order to prevent any ambiguity of meaning and to obtain simplicity of measurement. A brief *résumé* of these modifications may be of service.

The Committee propose that:—

(*a*) The freeboards to be tabulated shall be those which give the centre of the disc, and not, as at present, the winter freeboards.

(*b*) The tabulated freeboards shall be measured from the top of the actual deck at side, whatever may be the material of the deck, whether wood or steel, and not from an assumed wood deck at side, as in the present tables.

(*c*) The tabulated freeboards shall correspond to a standard sheer for both flush-deck steamers and vessels covered with a complete superstructure.

(*d*) Such standard sheer shall be greater for flush-deck steamers without forecastles than for the same type with forecastles.

(*e*) The standard sheer forward shall be twice the sheer aft.

(*f*) There shall be a minimum standard height of superstructure necessary to obtain a full freeboard allowance.

(*g*) The freeboard shall be determined with reference to the displacement block coefficient instead of the coefficient of fineness obtained from the under-deck tonnage.

(*h*) The allowances for special geographic and climatic conditions shall be simplified.

The other principal modifications proposed mainly arose from the desire to provide equality of treatment for the various types of vessels which are differentiated by the nature, extent, and disposition of the superstructures. It can readily be seen, provided suitable factors be chosen, that the freeboard for a vessel with detached superstructures may be derived from the allowance that is given to the same vessel when a complete superstructure is provided. Consequently it was decided that the Table of Freeboards should be laid down for a flush-deck vessel, and that the allowances for a complete superstructure above the flush-deck should be added to the same table. It thus became necessary to lay down two standards from which the geometric freeboard for any type of vessel might be obtained. These standard vessels are termed the standard flush-deck steamer and the standard complete-superstructure steamer. The characteristics of these standard types are defined in separate clauses, which regulate the ratio of the length of the vessel to the depth of the vessel to freeboard deck, the shear, round of beam, and height of superstructures. The manner in which the freeboards for vessels with detached superstructure are obtained from these two standards is of some interest. It is desirable that the allowances should take cognisance of—

(*a*) The total length of the flush deck, which is covered by superstructures, since, other things being the same, the ratio of the length covered to the length of the vessel should give the proportion of the full superstructure allowance to be taken.

(*b*) The manner in which the superstructures were disposed, since, *e.g.*, a forecastle of a given length affords better protection and involves better sea-keeping properties than a poop of the same extent.

(*c*) The nature of the appliances used for closing the openings in the end bulkheads of the superstructures, because a steel door permanently attached and suitably framed is, of necessity, less likely to fail than the same opening closed with wooden shifting boards.

The disposition of the superstructures is taken account of by means of what is termed a "type factor." This factor, with some classes of superstructures, for instance, "Three Island Vessels," remains constant whatever the total length covered. On the other hand, comparing the case of a combined bridge and poop, having collectively three quarters of the vessel's length, with only a poop which is 40 per cent. of the same length, it is reasonable to assume that the type factor should be greater for the former type of superstructure than for the latter. The highest value of type factor is given to that disposition in

which the bow, the waist, and the stern of the vessel are all protected, and the omission of superstructures at any one of these positions results in a decreased value of greater or less degree.

The nature of closing appliances for the end bulkheads of superstructures is taken account of by "the effective length ratio," which is given in a separate table. This table is based on the assumption that any detached superstructure can be described as either a forecastle, a bridge, a poop, or any combination of any two of these three classes. If Class I. closing appliances are provided, the effective length is taken as the actual length; while for Class II. appliances there is generally a reduction of 20 per cent. The case in which the bulkhead has no closing appliances is treated on the same footing as a case without bulkheads at all. With these two tables, the allowance to be given for any possible grouping of detached superstructures can be expressed as equal to the product

$$f.r.d,$$

where f is the type factor, r is the ratio of the sum of the effective lengths of the superstructures to the length of the vessel, and d is the reduction in freeboard allowed for the same vessel with a complete superstructure.

It might have been expected that the alteration in procedure detailed above would have resulted in considerable differences in freeboards from the practice which at present obtains. In order to examine the extent of such variations, a rather elaborate series of diagrams were prepared, and are attached to the report of the Committee. These diagrams clearly indicate that the divergencies of the proposed procedure are much less than might have been expected, and, generally speaking, such differences as occur are largely due to the favourable consideration which was formerly shown to one or more particular types.

It is not necessary to reproduce these diagrams here; but for the purposes of completeness of record, Fig. 1, page 350, will illustrate the nature of the comparison between the proposed procedure and present practice for vessels which have superstructures covering 70 per cent. the length of the vessel.

It will be seen that, where Class I. closing appliances are used, the new freeboards will be (1) the same as the present freeboards at a length of about 375 ft., and (2) slightly increased for shorter vessels. On the other hand, if the end openings of the superstructures have only Class II. closing appliances, the freeboards will in all cases be greater than those at present adopted.

It will be noticed that in places my remarks are to some extent paraphrases of sections of the report of the Committee. This has been inevitable, as my present object has been to put the matter in a form convenient for the purposes of our Institution. In conclusion, I may say that, if anyone will compare the new rules proposed by the Committee with those at present in operation, I think he will agree that a great advance has been made in clearness of expression, and that the procedure for the assignment of freeboard has been greatly simplified.

THE ROYAL SANITARY INSTITUTE.—A Conference on Sanitary Administration under War Conditions will be held in London, June 9 and 10. The Conference will be opened by the Right Hon. the Lord Mayor of London (Sir Charles C. Wakefield, Kt.), and a discussion on "The Maintenance of the Standard of Municipal Sanitation during the Continuance of War Conditions," will be opened by Mr. H. Percy Boulnois, M. Inst. C.E., and Mr. James Wheatley, M.D., D.P.H. On Saturday, June 10, at 10.30 a.m., a discussion on "The Mental Deficiency Act from the Social and Educational Standpoint," will be opened by Mr. A. B. Ritchie, M.B., C.M. Edin., Medical Officer, Manchester Education Committee.

NOTTINGHAM AS AN INDUSTRIAL CENTRE.—A booklet giving an account of the history, present condition, and future prospects of Nottingham has recently been officially issued by the Corporation of that city. Special attention is directed to its many advantages as a commercial and industrial centre, and also as a place of residence. Numerous sites are available for the construction of factories and commercial buildings, and this fact, together with its exceptional facilities for railway and water transport, for the supply of cheap fuel and power, and other important advantages from an industrial point of view, should be carefully considered by manufacturers desirous of extending their businesses or intending to undertake the manufacture of products formerly supplied by enemy countries.

THE MAKING OF A BIG GUN.—An interesting discourse on "The Making of a Big Gun" was given by Dr. W. Rosenhain, F.R.S., Superintendent of the Metallurgical Department of the National Physical Laboratory, before the Faraday Society, on April 6. Dr. Rosenhain dealt with his subject as exemplifying the ways in which the biggest masses of metal wanted for any purpose are being teemed, shaped, hardened and tempered, and finally put to use, illustrating by slides the changes which the treatment effects in the structure of the metal at different stages. His kinematograph pictures took his audience from the blast-furnace through all parts of the gun works. The photographs, he explained in his introductory remarks, had been taken in Messrs. Vickers' works in the winter of 1913-14. In proposing the vote of thanks, Sir Robert Hadfield, F.R.S., President of the Faraday Society, referred to the performances of modern guns and projectiles, adding the significant statement that the average active life of a modern gun—*i.e.*, the sum of the periods elapsing between the moment of firing a charge and the moment in which the projectile leaves the muzzle—did not exceed three seconds.

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several colonial and foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Australia: The Office of H.M. Trade Commissioner for Australia has forwarded a copy of a specification, &c., in connection with a call for tenders by the Commissioners of the Victorian Government Railways for the supply, delivery, and erection of a 2 ton electrically-operated goods-elevator at the car-shed, Jolimont, Melbourne (Contract No. 29,776). Tenders will be received at the offices of the Victorian Railway Commissioners, Spencer-street, Melbourne, up to 11 a.m. on May 17. Tenders must be accompanied by a preliminary deposit of ½ per cent. of the amount of the offer. Local representation is necessary.

Portugal: The *Diario do Governo*, Lisbon, notifies that tenders will be received at the Direcção dos Caminhos de Ferro do Sul e Sueste, Lisbon, for the construction of a railway station at Alcácer do Sal, on the Sado Railway. The contract will probably be awarded to a Portuguese firm, but we give this notice since the carrying out of the works may involve the purchase of some material outside Portugal.

Spain: The *Gaceta de Madrid* publishes a notice, issued by the Ministerio de Fomento, granting permission to Don Tomás Garmendia to utilise, at the rate of 2570 litres per second, the waters of the Reburdiejos and Sejos streams, in the district of Los Tojos (Province of Santander) for the production of electric power for industrial purposes. The necessary works must be commenced within a year, and completed within four years, from the date of the concession.

"TURBO-BLOWERS AND COMPRESSORS."

TO THE EDITOR OF ENGINEERING.

SIR,—Dr. Barclay, in his letter published in your issue of April 7, has pointed out a typographical error in the paper you recently published on the above subject. The pressure ratio in the expression given on page 144 should have appeared as $\frac{P_f}{P_o}$, *i.e.*, the ratio of the absolute pressures. This is apparent from the numerical values given in the example which immediately follows. The expression was given correctly at the top of the curve for work done in adiabatic compression (Fig. 16). The pressure p_o would be measured on the blower suction by a differential water gauge, the pressure at this point being less than atmospheric, so that if p_o is the indication on this gauge, then the absolute pressure at the suction P_o will be equal to $P_b - p_o$; this is apparent from Figs. 15 and 17. $P_b - p$ is, of course, the algebraic sum of the barometric pressure of the reading on the differential pressure gauge.

Yours faithfully,

H. L GUY.

Trafford Park, Manchester, April 12, 1916.

CRYSTAL PALACE ENGINEERING SOCIETY (AFFILIATED TO THE SOCIETY OF ENGINEERS).—The Wilson Premium for the best paper read before this Society during the past session has been awarded to Mr. H. M. Wilson for his paper on "Concrete." Other papers read before the Society were: "Petrol-Engines," by Mr. W. M. Wemyss, and "Railway Bridges and their Constructional Details," by Mr. C. L. C. Brock. The Premium was presented to Mr. Wilson by Mr. J. Patten-Barber, M. Inst. C.E., Past-President of the Society of Engineers and of the Institution of Municipal and County Engineers, at the 130th distribution of certificates at the above school, at which he presided on April 6.

THE IRON AND STEEL INSTITUTE.—The annual meeting of the Institute will be held at the Institution of Civil Engineers on Thursday and Friday, May 4 and 5. On the first day the Council will present their report; the acting President will move the adoption of the proposed new bye-laws, as amended at the autumn meeting, for incorporation in the bye-laws of the Institute, and will induct into the chair the President-elect (Sir William Beardmore). The Bessemer Gold Medal for 1916 will be presented to Mr. F. W. Harbord, F.I.C. The President will deliver his inaugural address. Papers Nos. 5 and 1 will be read and discussed. On Friday morning, May 5, papers Nos. 2, 4, 8, and 3 will be read and discussed. The following list of papers is expected to be submitted for reading and discussion:—1. "Notes on the Theory of the Corrosion of Steel," by Mr. L. Aitchison. 2. "Notes on the Relations between the Cutting Efficiencies of Tool-Steels and Their Brinell or Scleroscope Hardnesses," by Mr. J. O. Arnold, D.Met., F.R.S. 3. "A New Thermo-Electric Method of Studying Allotropic Changes in Iron or other Metals," by Mr. C. Benedicks, Ph.D. 4. "Initial Temperature and Critical Cooling Velocities of a Chromium Steel," by Mr. C. A. Edwards, D.Sc. 5. "The Influence of Carbon and Manganese upon the Corrosion of Iron and Steel," by Sir Robert Hadfield, D.Met., F.R.S., and Mr. J. N. Friend, D.Sc. 6. "Early Experiments on the Recalescence of Iron and Steel," by Mr. A. Mallock, F.R.S. 7. "A Few Experiments on the Hardness-Testing of Mild Steel," by Mr. W. N. Thomas, B.Sc. 8. "Surface-Tension Effects in the Intercrystalline Cement in Metals and the Elastic Limit," by Mr. F. C. Thompson, M.Met., B.Sc. The autumn meeting will be held at the Institution of Civil Engineers on Thursday and Friday, September 21 and 22.

MAXIMUM PRICES OF IRON.

THE question of the price of material used and produced in the iron and steel industries has been under the consideration of the Minister of Munitions for some time past; and, after consultation with the representatives of the principal trade associations, the following maximum prices for the various products have been fixed until June 30, 1916, and thereafter until further notice. The makers may sell for delivery after June 30, 1916, on the understanding that the fixed maximum prices ruling on the first day of any month during the period of the contract will apply to all deliveries made during that month. These maximum prices are based upon the abnormal costs and conditions now prevailing, and must not be assumed to be indicative of any difference in relative values which may have obtained in the several districts before the war and may obtain again after the war. This intimation must not be taken to authorise any sale or purchase or other dealing prohibited under the Defence of the Realm Regulations:—

	Per Ton Net F.O.T. Makers' Works. £ s. d.
Hematite Pig-Iron (West Coast):	
Mixed Nos. 1, 2, and 3	6 7 6
Special quality, containing under 0.03 of phosphorus and sulphur	6 15 6
Special quality, containing under 0.02 of phosphorus and sulphur	7 0 0
Hematite Pig-Iron (East Coast):	
Mixed Nos. 1, 2, and 3	6 2 6
Special quality, containing under 0.03 of phosphorus and sulphur	6 15 6
Special quality, containing under 0.02 of phosphorus and sulphur	7 0 0
Hematite Pig-Iron (Scotch):	
Mixed Nos. 1, 2, and 3	6 2 6
Special quality, containing under 0.03 of phosphorus and sulphur	6 15 6
Special quality, containing under 0.02 of phosphorus and sulphur	7 0 0
Hematite Pig-Iron (Welsh):	
Mixed Nos. 1, 2, and 3	6 2 6
Special quality, containing under 0.03 of phosphorus and sulphur	6 15 6
Special quality, containing under 0.02 of phosphorus and sulphur	7 0 0
Lincolnshire Pig-Iron:	
Basic or foundry	4 7 6
Cleveland Pig-Iron:	
Mixed Nos. 1, 2 and 3	4 2 6
Northamptonshire Pig-Iron:	
Forge	4 2 6
Foundry numbers	4 5 0
Derbyshire Pig-Iron:	
Forge	4 5 0
Foundry numbers	4 7 6
North Staffordshire Pig-Iron:	
Forge	4 10 0
Foundry	4 12 6
Basic	4 15 0
South Staffordshire Pig-Iron:	
"Part Mine" forge	4 10 0
" foundry	4 12 6
Common Staffordshire	4 5 0
"All Mine" forge	5 10 0
" foundry	5 15 0
"Warm Air" forge	7 0 0
" foundry	7 10 0
Special quality, Lord Dudley's silicon	7 17 6
Cold-blast iron	8 17 6
Scotch Foundry and Forge Pig-Iron:	
Nos. 3, 4 and lower grades of Monkland, Dalmellington, Eglinton, and Govan	5 14 0
Nos. 3, 4 and lower grades of all other brands	5 15 6
No. 1 quality	In all cases to be 5s. per ton above these prices

---

OUR LOCOMOTIVE EXPORTS.—The war continues to materially reduce our shipments of locomotives and parts of locomotives to British colonies and foreign countries. The value of the engines shipped in March was only 74,024*l.*, as compared with 247,535*l.* in March, 1915, and 453,465*l.* in March, 1914. The value of the exports to March 31, this year, amounted to 350,487*l.*, as compared with 759,013*l.* in the first quarter of 1915, and 1,224,672*l.* in the first quarter of 1914.

THE AMERICAN NAVY.—The Senate of the United States has passed, by 58 votes to 23, what is known as the "Tillman Bill," appropriating 11,000,000 dols. for the purchase or construction of a Government armour-plate factory, with a capacity of 20,000 tons per annum. The Bill now goes to the House of Representatives' Committee on Naval Affairs, by which it will probably be favourably reported after the annual Naval Appropriation Bill has been disposed of.

SIX MORE AEROPLANES FROM MALAYA.—A further example of the enthusiasm displayed by the British Colonies and Dependencies for the cause of right and justice is afforded by the following paragraph taken from *The London and China Telegraph*, which says that: "In addition to over 15,000*l.* previously subscribed, 10,500*l.* has been collected in the Straits Settlements and the Federated Malay States for the purpose of six more aeroplanes, which will be numbered Malaya 11 to Malaya 16, for the use of the Royal Flying Corps. Mr. C. Alma Baker, of Kinta, who is the organiser of the fund, and has himself already given one aeroplane, is the donor of a second aeroplane.

PARTS OF 18,900 K.V.A. SINGLE-PHASE ELECTRIC GENERATOR; RJUKAN II. POWER-STATION, SAAHEIM, NORWAY.

CONSTRUCTED BY THE SWEDISH ELECTRICAL COMPANY, ENGINEERS, VASTERAS.

(*For Description, see Page* 344.)

FIG. 8. ONE-FOURTH OF THE STATOR.

FIG. 9. THE ROTOR.

FIG. 10. THE CENTRE OF THE ROTOR.

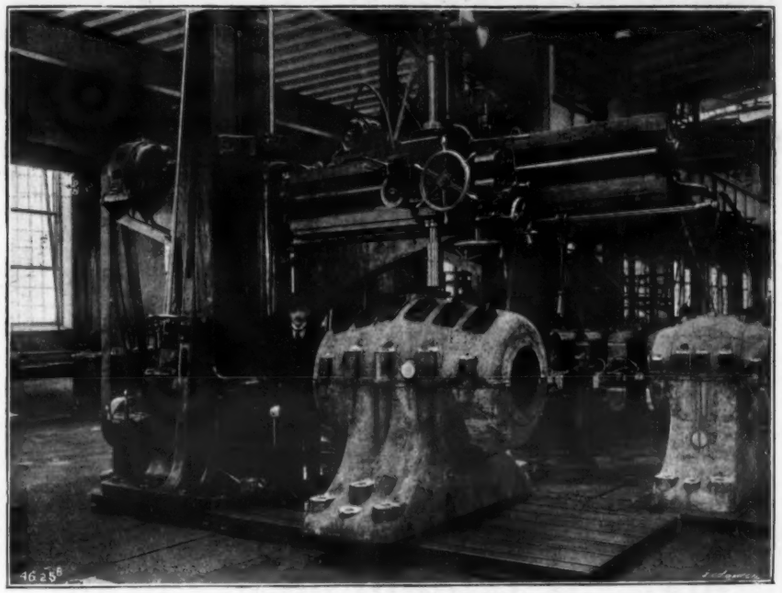


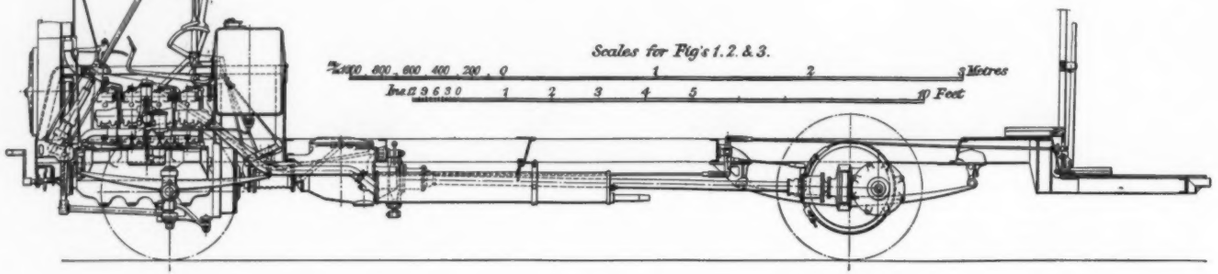
FIG. 11. ONE OF THE BEARINGS.

THE PARIS MOTOR-BUSES IN WAR SERVICE; THE SCHNEIDER CHASSIS AND ENGINE.

CONSTRUCTED BY MESSRS. SCHNEIDER AND CO., ENGINEERS, PARIS AND HAVRE.

(*For Description, see Page* 343.)

Fig. 1.



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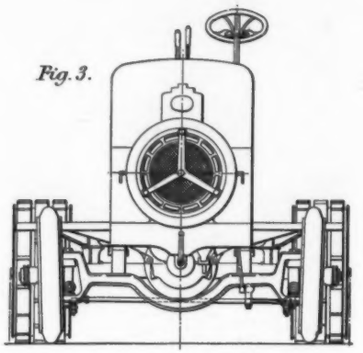

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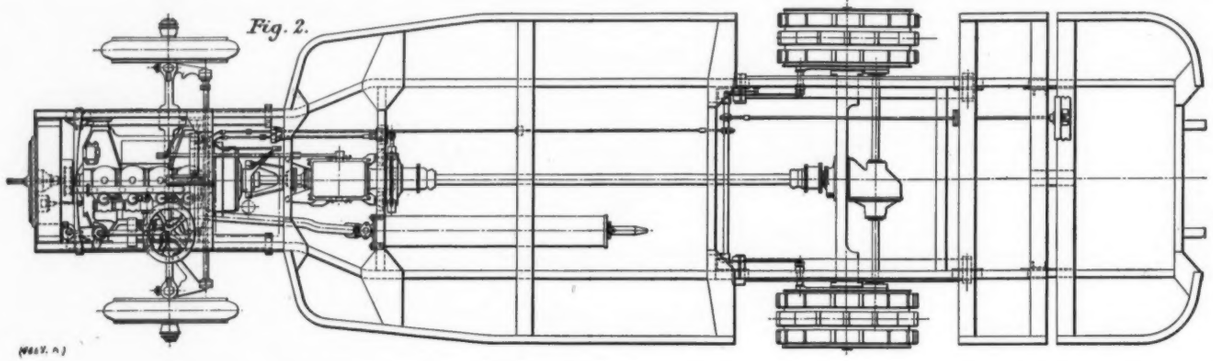

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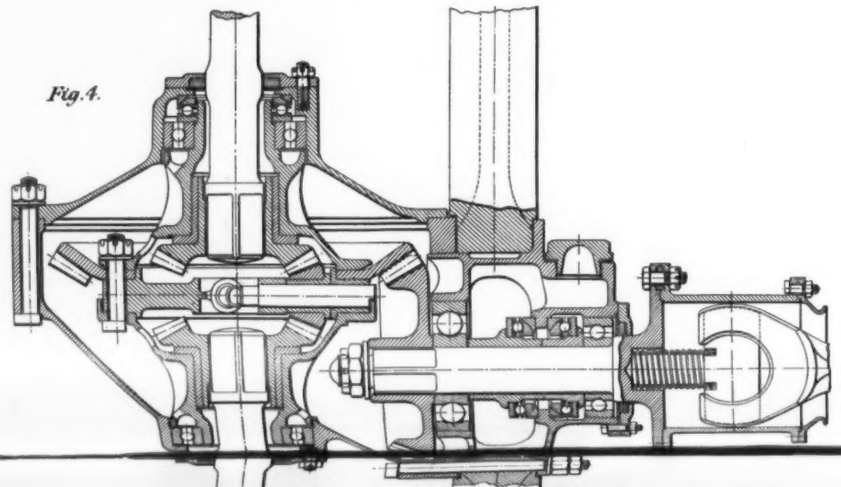

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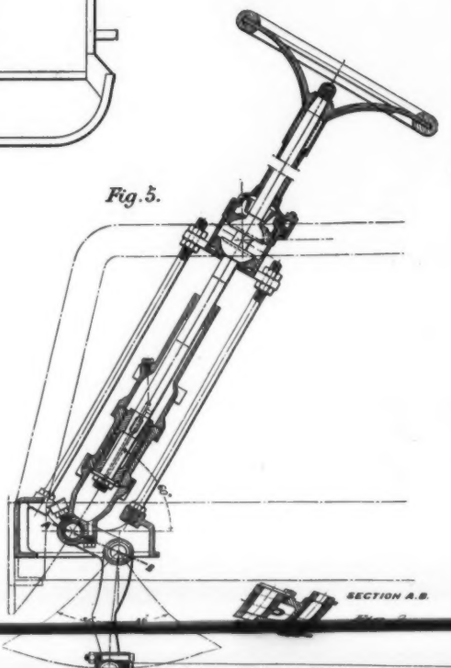

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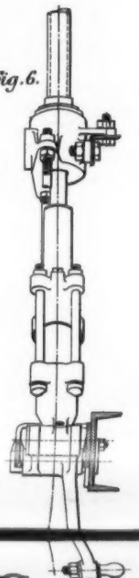

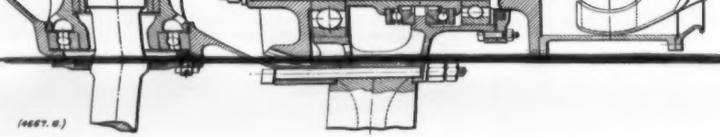

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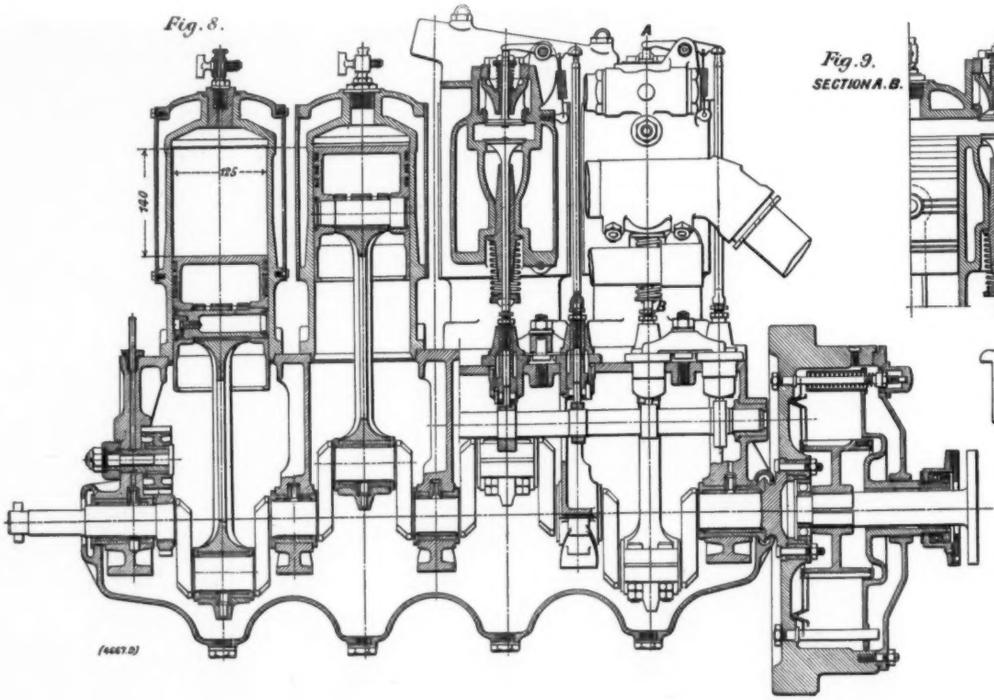


Fig. 9.
SECTION A.B.

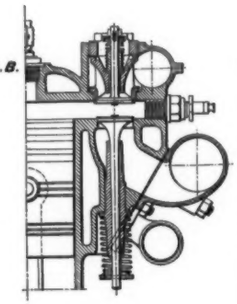


Fig. 10

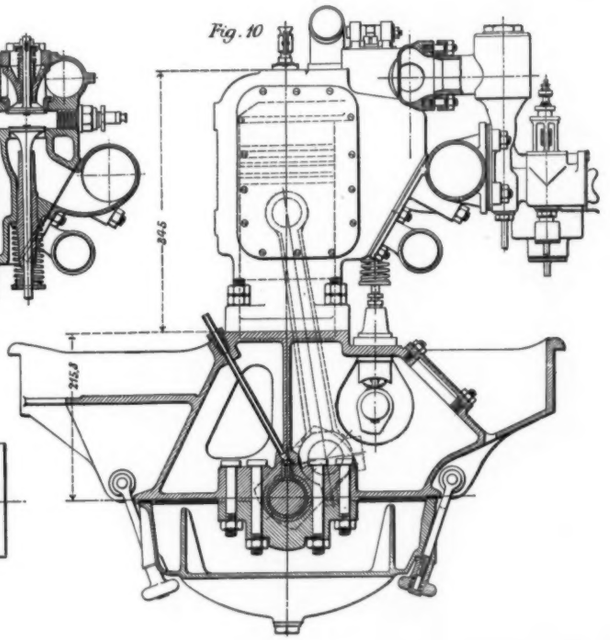
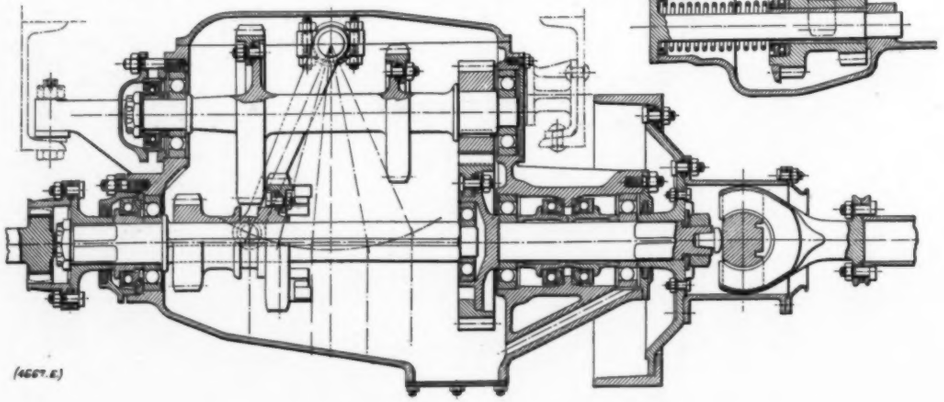


Fig. 11.



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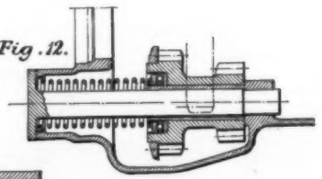
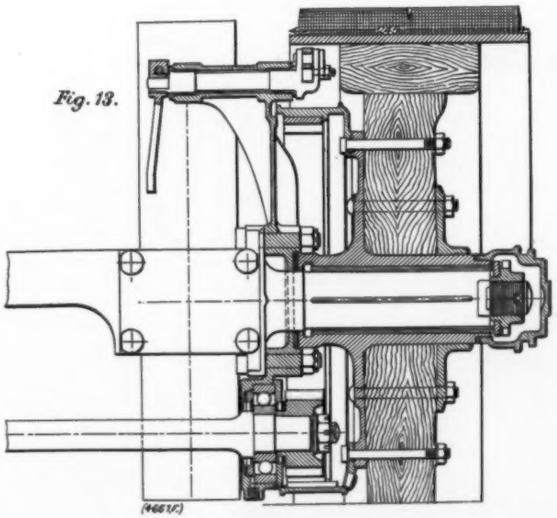


Fig. 13.



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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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Thin paper copies	£1	11	6 ($7.65)
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Thin paper copies	£1	16	0
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Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C.

Offices for Publication and Advertisements, 35 and 36, Bedford-street, Strand, London, W.C.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3663 and 8596 GERRARD.

S.S. "PERSIA" AND S.S. "MALOJA."

The Publisher desires to notify subscribers to "ENGINEERING" in the East who did not receive their copies of "ENGINEERING" of the issues of December 17, 1915, and February 25, 1916, that they may have gone down with the mails in the S.S. "Persia" and S.S. "Maloja." A few copies are still in stock of each of these issues, and may be secured at the ordinary rates, plus postage.

CONTENTS.

	PAGE
The Running of Boiler Plants and National Economy	341
The Spectra of Hydrogen and Helium	342
The Paris Motor-Buses (*Illustrated*)	343
Three-Phase Generators for Rjukan II. Power-Station at Saaheim, Norway (*Illustrated*)	344
Industrial Notes	346
Progress of Merchant Shipbuilding	346
Notes from the North	346
Notes from South Yorkshire	347
Notes from Cleveland and the Northern Counties	347
Notes from the South-West	347
The Parodi Periscope (*Illustrated*)	348
Michell Journal Bearing (*Illustrated*)	348
The Load-Lines of Merchant Ships: Work of the Load-Line Committee (1915) (*Illustrated*)	348
Colonial and Foreign Engineering Projects	351
"Turbo-Blowers and Compressors"	351
Maximum Prices of Iron	351
The Engineer and his Assistants	353
Radiations from Atoms and Electrons (*Illustrated*)	354
The late Sir Colin Campbell Scott-Moncrieff	356
The Institution of Naval Architects	357
Notes from the United States	360
Multiple-Spindle Sensitive Drills (*Illustrated*)	361
Some Questions in Connection with the Work of the Load-Line Committee (*Illustrated*)	361

With a Two-Page Plate of the PARIS MOTOR-BUSES IN WAR SERVICE: THE SCHNEIDER CHASSIS AND ENGINE.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, April 14, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. Subject of paper: "Theory and Practice in the Filtration of Water," by Mr. Walter Clemence, Member.

THE PHYSICAL SOCIETY OF LONDON.—Friday, April 14, at 5 p.m., at the Imperial College of Science, Imperial Institute-road, South Kensington, S.W. Agenda: 1. "The Variation of Resistance with Voltage at a Rectifying Contact of Two Solid Conductors, with Applications to the Electric Wave Detector," by Mr. D. Owen, B.A., B.Sc. 2. "The Electrical Capacity of a Gold Leaf Electroscope," by Mr. T. Barratt, A.R.C.S., D.Sc.

THE BRITISH FOUNDRYMEN'S ASSOCIATION; LANCASHIRE BRANCH.—Saturday, April 15, at 7 p.m. A special meeting will be held at the Lyceum, Oldham, when a lecture will be delivered by Mr. J. G. Robinson, of Halifax (late foundry manager of the Campbell Gas-Engine Company), entitled "A Day in a Foundry."

THE CLEVELAND INSTITUTION OF ENGINEERS.—Monday, April 17. Paper by Dr. W. H. Hatfield, on "Precipitation of Free Carbon in Iron and Steels."

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 18, at 5.30 p.m. Annual general meeting of Corporate Members only, to receive the report of the Council, and to elect the Council and auditors for the ensuing year.

THE LONDON SOCIETY.—Tuesday, April 18, at 5.30 p.m., in the Hall of the Royal Society of Arts, 18, John-street, Adelphi, W.C. Mr. W. R. Davidge, F.S.I., will give a Lantern Lecture on "The Development of London." Sir Aston Webb, K.C.V.O., C.B., R.A., will take the chair.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday April 19, at 7.30 p.m., at 70, Victoria-street, Westminster. Papers to be read: 1. "The Persistence of Wet and Dry Weather," by Mr. E. V. Newnham, B.Sc., F.R. Met. Soc. 2. "Discontinuities in Meteorological Phenomena." Second Note, by Professor H. H. Turner, D.Sc., F.R.S.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, APRIL 14, 1916.

THE ENGINEER AND HIS ASSISTANTS.

THERE are certain occupations in which a man can design and complete his work himself. The painter, the literary man, the musician, can labour in solitude, and their products are the fruits of their own brains. But with the engineer the case is quite different. He has largely to see through other persons' eyes, to hear through their ears, and to act through their hands. The day is not long enough for him to take personal cognisance of everything for which he is responsible, and he must act to a great extent through subordinates. When they serve him well he gets the credit, and when they serve him ill he bears the blame. It is therefore of immense importance to him, and to the firm he represents, that he should, in the first place, select his assistants with skill, and, in the second, imbue them with a spirit of loyalty. Nothing conduces more to good service than the knowledge among the rank and file that the chief can take any job out of their hands and do it as well, or better, than themselves. In early years this state of affairs is quite possible, but later, as the province under a man's control widens, he can no longer be an adept in every department. Then his method of influencing those below him must be moral and intellectual, rather than technical. He must be a student of character, able to discern both the strong and the weak parts of his assistants. He must encourage the diffident, stimulate the lethargic, and repress the erratic. There are no books that explain how this is to be done, and no professors that lecture upon the art. It can only be acquired by constant effort, and this effort must be begun while a man is young, long before he has much opportunity of putting the lessons into practice. If the careers of the great men of the world be studied, it will be found that they were always surrounded with capable assistants of their own choosing. The ability to discern merit was one of the main features in their success. To a great extent this is instinctive, but it may be cultivated if the matter is taken in hand early in life. A man who aims to rise to posts of great responsibility must practise the study of character with assiduity while he is able to be on familiar terms with his fellows. As he grows older he will find that a veil will gather between him and his acquaintances. They will no longer allow him the easy familiarity that he once enjoyed. He cannot gaze into the depth of their dispositions with the facility he once did, and his opportunities of studying human nature gradually curtail. If he has not laid the foundations of the knowledge, he will find it almost impossible of attainment when he needs it most.

In the early part of an engineer's career he generally finds those whom he directs chosen for him, and often they have reached that period of life when it is difficult to effect any great change in them. Workmen, for instance, are brought up in a narrow school, and their limitations must not be forgotten. The assistant-manager of a works will attain greater success by adapting himself to their standpoint than by seeking to transform theirs. The men in a works are much like the material they treat. They have certain qualities and certain defects—like the rest of us—and these have ever to be borne in mind when it is proposed to adapt them to a given purpose. If the engineer could evolve his material out of his brain, as he does his design, there would be no limit to which he could achieve. Such an idea is, of course, Utopian. Both men and metals give way under undue stress, and it is only within certain bounds that they have any value. It is the business of those who deal with them to gauge the extent of their capabilities, and to make the best use of the qualities that lie within them. To go further is to court disaster. A manager may sometimes writhe under the limitations of his *personnel*, but it is just as absurd for him to ascribe his failures to the incapacities of a class as it would be to denounce cast iron because it snapped under a tension load. His art lies in adapting his designs to the material at his command at a given time.

It is not only workmen, however, who have to be accepted by those put over them. Foremen, draughtsmen, and assistant-engineers generally are appointed by others, and it is a matter of difficulty to get them removed. This is by no means an ultimate disadvantage to the aspiring assistant-manager, although it may cause him much trouble. If he could scrap the human wasters as readily as those from the foundry, he would be saved many a disappointment; but, at the same time, he would forego the benefit he attains by the exercise of patience and insight, and he would not learn the art of getting the best out of the material supplied to him. A very apt metallurgical analogy to the careful education of assistants is to be found in the series of processes described as "heat treatment." It is a comparatively short time since engineers learned how to improve the qualities of steel by subjecting it to certain ranges of temperature. Before that they were very much at the mercy of those who had handled the metal before, and who might have left it in a condition far below that to which it could be brought. Of course, there were flagrant defects, such as red-shortness and cold-shortness, which justified the immediate scrapping of material; but apart from these, thousands of tons of steel were used in a condition below that which can now be attained. As the result of study and experiment, it is now possible to bring steel by fairly simple means into a state in which its various qualities are at their best. Something of the same kind is possible with human material, but unfortunately the process cannot be systematised in the same way so as to be carried out by any person capable of using a pyrometer. That its possibility is known is evidenced by the phrase, constantly seen in advertisements, "used to the control of men." An untactful foreman can make trouble for his firm more effectually than an incompetent furnaceman, while an autocratic, though technically skilful, manager may waste the profits in useless strikes. Such difficulties and losses are, in some measure, avoidable, provided those in command have a natural ability for guiding and placating those below them, and give the necessary care and study to the subject. It is seldom realised by owners and directors how great is the money value of a judicious combination of tact and firmness in a manager, and to what extent it may compensate for want of skill and experience in other directions. If, like heat-treatment on metal, it causes the human material to display its better characteristics, rather than its worst, then it will do more for efficiency than the newest and most aggravating card system fresh from the States.

We have, however, wandered somewhat from our immediate subject, which is the dependence of the engineer on his assistants, and the necessity of his spending effort on their education. We have nothing to say about the man who, like

Napoleon, can gauge a new-comer at a glance, and can attract talent to his side by his personal magnetism. He will be well served in any case. But genius of that order is rare, and most engineers will find the time well spent they devote to the training—moral as well as technical—of their staff. It seems almost a truism to say such a thing were it not a matter of common knowledge that this subject is so often neglected. It is a characteristic of the present day that more and more is spent by engineers on apparatus of precision. There are found in works, gauges, measuring-machines, pyrometers, and balances of a delicacy that a few years ago was scarcely to be met with in the laboratory. These can be bought by anyone, but they represent an immense amount of thought and experiment on the part of their makers and others. Unfortunately, assistants cannot be obtained like instruments, guaranteed to do the right things under all circumstances within a minute fraction of perfection.

Every engineer has to standardise his own assistants, and tune them up to the degree of efficiency which is required for the class of work that he does. This involves much trial and error; but the matter is immensely simplified if he has the ability to recognise the right kind of raw material when he sees it. If he has made the best of his early opportunities for forming a correct estimate of men, he will be able to reject at a glance many a candidate for his employment who comes armed with satisfactory testimonials. Further, he will feel instinctively how each man should be treated. In a works it is generally necessary to pursue a collective system; but in an office individual treatment is not only possible but necessary. There is probably no man, however earnest, or however skilful, that cannot be induced to do better work by judicious assistance or pressure. When we remember that the reputation and profits of an engineer depend very largely upon the way in which his instructions are carried out, it becomes evident that no pains are too great to spend on the instruments by which he works. Each improvement in them is like a judicious investment in labour-saving machinery, and will bring in a return year by year. The ability to form a correct judgment of character is one of the most valuable assets a professional man can have, and although it is not so attractive to the young as technical knowledge, it is quite as well worth attainment.

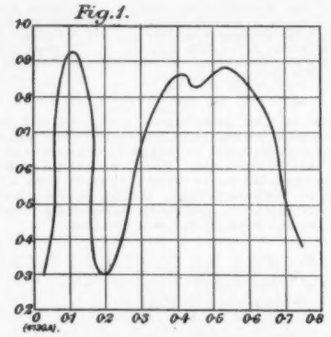
RADIATIONS FROM ATOMS AND ELECTRONS.

IN opening his fifth lecture at the Royal Institution on the above subject last Saturday afternoon, Sir J. J. Thomson, O.M., P.R.S., said that at the end of the last lecture he had pointed out that the Doppler principle provided a method of determining the nature of the system to which were due the various lines observed in the spectrum of a gas. The idea of the method we owed to Stark. In applying it, a discharge tube was used having a perforated negative electrode. The stream of positively electrified particles which passed, with great velocity through this cathode into the gas behind, produced light, the spectrum of which was examined. Some of the lines of this spectrum were then found to be displaced from their normal positions, whilst other lines were unaffected. The character of the results obtained was, he said, represented in Fig. 1, which represented the variations in intensity observed in the immediate neighbourhood of one of the hydrogen lines.

With this gas there was considerable luminosity in the normal, or "rest," position of the hydrogen line, and this was represented in the diagram by the first peak. Following this there was a comparatively dark space, and then came a second peak, which represented the displaced position of the line. This displacement was produced, on the Doppler principle, by the motion of the luminous particles towards the observer. It would be seen that not only was the line displaced, but it was also considerably broadened, owing to the fact that the velocities of the luminous particles differed amongst themselves to a very great extent. The light represented by this second peak must have been given out by moving particles, or it would not have been displaced. Hence one of the systems that came through the opening in the cathode was the source of this displaced hydrogen line. The particles thus passing were, however, a very mixed lot. This was well shown by Fig. 2, which showed the paths traced on a photographic plate when bombarded by positive rays produced in air by the method he had often described in that room. Each trace was made by a different system of particles, and it would be seen that not only were these systems numerous, but each gave a trace of considerable length. Consider, for example, the line corresponding to CO. If all the particles of this gas passed through the cathode with the same velocity, the long line shown would have been contracted up into a single bright spot. That the trace was stretched out, in the fashion represented, showed that different particles of this gas had different velocities, and hence had different displacements from an axis drawn through the central spot. The velocity of the particles corresponding to any point of the trace could be determined by measuring the vertical displacement, as this was directly proportional to the height above the horizontal axis of the figure.

Returning to the discussion of the Doppler effect

Fig. 1.



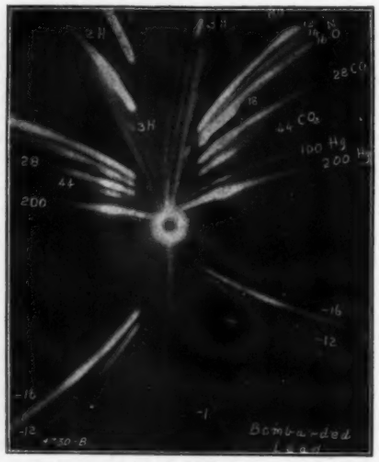


FIG. 2.

Sir Joseph Thomson observed that since heavy particles like those of mercury moved more slowly than lighter ones, the displacement of the spectral lines would be less, so that from the amount of this displacement it was possible to determine whether the particles concerned were heavy or light. Very considerable care was, however, necessary in interpreting the spectroscopic observations. It would be observed that the displaced hydrogen line in Fig. 1 showed two peaks, one of which was much nearer the "rest" position of the line than the other. Actual measurement indicated that the ratio of the velocities corresponding to these two peaks was not very different from $\sqrt{2} : 1$. Now this ratio was that which the velocity of an atom of hydrogen would bear to that of a molecule. It had been contended accordingly that the light represented by the displacement in Fig. 1 was given out both by atoms and by molecules of hydrogen.

Sir Joseph Thomson said he did not think that this interpretation was a legitimate one. If we studied the distribution of the velocities in diagrams of the kind represented in Fig. 2, a peculiarity quite analogous to the double peaks in Fig. 1 could often be observed. The hydrogen line, for example, would at first be fairly uniform, but later became beaded at certain places, after which the line became more uniform. Now the centres of the two beads were exactly at points corresponding to velocities having the ratio of $\sqrt{2}$ to 1. Spectroscopic observations would show maxima corresponding to these two velocities, and we would get exactly the appearance of the diagram reproduced in Fig. 1, although the beads in question were produced by the atom of hydrogen, and not by the molecule. The explanation of the peculiarity was that the particle responsible for the lower velocity had acquired its speed whilst still part of a molecule, but broke up after getting through the cathode. It had therefore only the velocity corresponding to a molecule. These considerations showed how important it was to check the spectroscopic observations. This beaded appearance was often to be seen in positive-ray photographs, and whatever showed as beads on them would be represented as peaks in the spectrum, and might lead, as he believed it had done in the case cited, to an entire misinterpretation of the results.

If the spectrum of hydrogen were observed as described, it was found that the series of lines represented by Balmer's formula were all displaced, and by about the same amount. The second spectrum of hydrogen, to which Balmer's lines did not belong, was also to be seen. This second spectrum was a very complicated one, having an enormous number of fine lines, particularly in the red and the orange, which had the peculiarity that none of them showed any displacement in Stark's experiments, but continued to occupy their normal positions. Only "series" lines were, in fact, displaced.

An interesting question thus arose as to the origin of the second spectrum of hydrogen. Photographs such as that reproduced in Fig. 2 showed that not merely charged atoms, but charged molecules, came through the perforated cathode. Thus, in the case of hydrogen, we had atoms of hydrogen, molecules of hydrogen consisting of two atoms, and molecules of hydrogen consisting of three atoms. All three were in rapid motion, and any light emitted by them would show the Doppler effect. It followed therefore that the second spectrum of hydrogen could not be given out by anything that came through the hole in the cathode. It could thus not be attributed either to the positively-charged atoms or to positively-charged molecules, and must have as its source something that had not passed through the cathode. Possibly it arose from the vibrations of a molecule one of whose atoms was positively and the other negatively electrified. That this second spectrum was certainly not due to the positive rays themselves could be shown by causing positive rays of one gas to bombard the molecules of another. This had been done by perforating the cathode by a very fine hole, and making this hole the only means of communication between the two sides of the cathode. By means of a pump it was possible to prevent any appreciable intermixture of the gases on opposite sides of the cathode. The positive rays were then provided entirely by particles of the one gas, and spectroscopic observation showed that all the lines corresponding to this gas were displaced, whilst those belonging to the other gas all occupied their normal positions, and were not displaced. This was, of course, exactly what would have been expected, but it was always pleasing to have such anticipations verified by actual experiment.

It would be seen that whilst the spectroscope served as a very powerful instrument of research, there was some little difficulty in drawing really definite conclusions from the observations made. One point, in fact, was still in a state of acute controversy—viz., were the lines of, say, hydrogen given out by the atom whilst it was positively electrified, or after it had become neutral by re-acquiring a negative charge. This question was still debated, and it could not be said that any kind of unanimity of view had yet been arrived at. It would, however, require very powerful evidence to make us believe that the line spectrum of hydrogen was emitted whilst the hydrogen atom was still positively charged, since we had, in the Zeeman effect, means of finding out the nature of the actual vibrator responsible, whether it were an atom or an electron. The Zeeman effect showed conclusively that the line spectrum originated in vibrating electrons.

Now data drawn from many independent sources

gave reason for the belief that a neutral atom of hydrogen contained only one electron, so that it was not possible to take out more. The positively-charged atom of hydrogen was accordingly one which had lost its electron. Hence very strong evidence would be required to establish the view that it was a positively-charged atom of hydrogen which was the source of the line spectrum.

The speaker's own view was that both the contending schools were, in a sense, right. To get the line spectrum it was necessary for the atom to have lost its electron so as to become positively charged, but it was only as an electron came back that the light was given out in the process of the atom becoming neutral. This union of the positively-charged atom with an electron was made, more particularly, during the instant of a collision with a molecule of the gas through which the atom was moving. Professor Strutt, for example, had subjected the gas bombarded by the positive rays to a strong electric field, which would have the effect of driving out any free electrons. He found, and similar experiments made by the speaker gave the same results, that the brightness of the lines produced was very little diminished by the action of the field.

Referring back to Fig. 1, it would be seen, Sir Joseph proceeded, that there was a marked gap between the normal and the displaced position of the hydrogen line. Apparently nothing less than a certain displacement was to be obtained. Again, as the velocity of the particles was increased we appeared to approach a second limit, as it had not been found possible to get more than a certain displacement of the line even when the theoretical velocity of the rays was much greater than that necessary to produce the maximum displacement observed. Now it was well known that to ionise a gas the speed of the positive rays must exceed a certain limit. On the other hand, if the speed were too great there was very little ionisation. The actual luminosity would accordingly appear to be due to the return to neutrality of the positive ray in the act of ionising the molecule of the gas with which it collided.

A still further advance in the application of the Doppler principle to the study of the origin of luminosity had been made recently by Fabry and Perot. Their method was founded on one of those ideas, which, like the echelon grating, one would consider impracticable until it was actually made to work. These experimenters had applied Doppler's principle to the study of the luminosity of a gas by observing the broadening of the spectral lines due to the motion of the gaseous particles. These were in continual motion, some moving towards an observer, and others away from him. The result was a broadening of the spectral line by an amount depending on the speed of the particle, and, as Lord Rayleigh had observed, the actual breadth corresponded very fairly with the average velocity with which the molecules were moving through the gas. If, therefore, the origin of a spectral line were a light atom, this would have a very high velocity, and the widening be correspondingly great. If a heavy atom were responsible, the widening would be less. Hence accurate measurements of the widening would suffice to determine the average velocity of the particle responsible for the emission. Then from the law that all particles in a gaseous mixture had the same kinetic energy the mass of the particle could be determined. This beautiful conception was the more important because so many lines showed a velocity effect. The only point open to suspicion in the experiments in question was whether a charged particle would have the velocity normally due to it. This could be settled by a comparison with results obtained by Stark's method in conditions in which both methods were applicable. If the reliability of the new plan was thus confirmed, full confidence could be placed in the interpretation that Messrs. Fabry and Buisson put on their results. If the method really did give the velocity of the atom bearing the vibrating system which was responsible for the spectral lines, the method could be applied to many cases where Stark's plan could not be used.

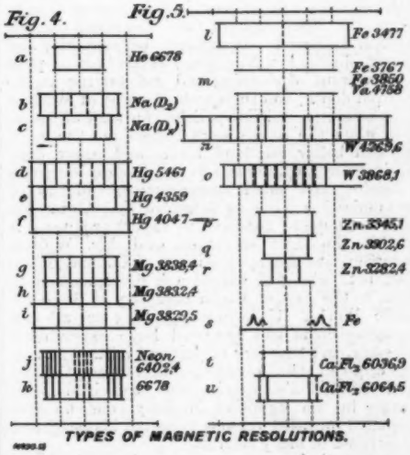
As he had already mentioned, the Zeeman effect showed the nature of the source from which light was emitted, whether it were due to an electron or to a body of very much greater mass. In this connection, however, it should be noted that to produce visible light the electron must be associated with an atom, since direct radiation from a free electron had never yet been observed in the spectroscope. Were this possible, the displacement would be enormous, owing to the immense speed of the electron. The Zeeman effect had, however, no reference to free electrons, but only to electrons associated with an atom.

Faraday, years ago, had sought to discover some effect of magnetism on light. He did find that a magnetic field could be made to rotate the plane of polarisation of polarised light, but he had failed to observe any effect of magnetism on the light given out by, say, a sodium flame. Effects of this kind had, however, been discovered by Zeeman on studying the spectrum of various substances as excited by a spark passed between the poles of a very strong magnet. Zeeman found that in strong fields the lines observed were not in the same position as they were when the magnetic field was absent. Single lines were broken up, in the original experiments, into three components. More extensive study had, however, shown that the type of resolution effected varied considerably, being in certain cases very complicated.

This power of a magnet to resolve a spectral line into components depended upon the mass of the particle responsible for the emission, being exceedingly small. In fact, investigations made prior to

Fig. 3.

Fig. 4. *Fig. 5.*



TYPES OF MAGNETIC RESOLUTIONS.

Zeeman's experiments gave expressions which led to the idea that the light emitted in a magnetic field should not be quite the same as normally; but when these expressions were expressed numerically, it appeared that, assuming the emitting particle to have the smallest mass then known, the effect would be so minute that it would be hopeless to look for it. At that time, in fact, there was no knowledge as to the existence of particles smaller than the atom, and Zeeman's success was due to the fact that such particles or corpuscles actually existed.

The lecturer here showed the effect of a magnetic field on the corpuscles moving in a discharge-tube. With no magnet near, the particles, he observed, moved in a straight line; whilst the effect of bringing near the discharge a strong magnet was to curl round their paths into circles or spirals having the lines of magnetic force as axes. When these particles spun round the lines of magnetic force in this way, a peculiarity of the motion was that the time taken to complete one revolution was always constant. It did not matter how big the spiral might be nor how small. If close in to the axis the particles moved more slowly, whilst if further out the speed increased, with the result that the time for a complete rotation was constant. In short, the number of rotations made per second was proportional to the expression $\frac{H e}{m}$, where H denoted the magnetic force, e the charge of electricity borne by the particle, and m its mass, so that in a uniform field the time depended solely on these three quantities. Suppose, now, that inside the atom represented by the circle in Fig. 3 there was a magnetic field the direction of which was represented by the vertical line shown. An electron falling into the atom would describe a spiral around this axis of magnetic force, and throughout its motion the rate at which it revolved would be proportional to $\frac{H e}{m}$. It would therefore radiate out a spectral line having the corresponding frequency.

The magnetic force represented in Fig. 3 was assumed to be that intrinsic to the atom; but suppose an additional field H_o, due to an outside source, were established, and let this field be parallel to the atomic field. Then, if the two fields were in the same direction, the particle would make, not $\frac{H e}{m}$ turns in unit time, but $\frac{H + H_o}{m} e$ turns. On the other hand, if the two fields were in opposite directions, the number of turns made would be $\frac{H - H_o}{m} e$, and the frequency of the light emitted would be less than if the external field were cancelled. On the other hand, if the applied field were perpendicular to the intrinsic field, the turns made by the rotating electron would be unaffected. Hence, in a magnetic field the frequency of some of the electrons would be increased, the motion of others would be retarded, whilst for a third set it would be unaffected. Hence by superimposing a field on that due to the atom itself we should alter the time of vibration of the light given out, and instead of the normal single line we should get three lines, one in the original position and the other displaced from this by an amount proportional to $\pm \frac{H_o e}{m}$.

In the foregoing he had, he said, used the idea of a magnetic axis intrinsic to the atom for descriptive purposes, but he did not propose to press the idea at this time.

As he had already stated, further research on the Zeeman effect showed the resolution of spectral lines into a great number of different types. A number of these were represented in Figs. 4 and 5. In the simple type shown at the top of Fig. 4 one line was resolved into three components. This was the case with helium and with some of the hydrogen lines, and was especially common with the lighter elements up to lithium. With sodium, as the diagrams showed, there was greater complexity, one of the lines being split into five, and the other into four components. In the case of the mercury spectrum it would be seen that some lines divided into three, others into six, and a third set into nine components. The noteworthy point was that all the lines belonging to the same series underwent the same type of resolution. In the case of neon, the resolution was, it would be seen, of an extraordinarily complex type. On the other hand, in the case of iron (Fig. 5), one line was not broken up at all, whilst others were resolved into as many as five components. The resolution of a line showed that it came from an electron, and not from an atom, which was much too heavy. Band spectra did not show the Zeeman effect, which was to be obtained with line spectra only. It had been found that some lines in the second spectrum of hydrogen were affected, but the vast majority of the lines in this certainly did not show the effect.

If one took the view that there were magnetic forces inside the atom, the variety of types of resolution obtained could be explained on the hypothesis that there were axes of magnetic force in an atom, somewhat similar to the axes of a crystal. Suppose these axes of magnetic force were represented by O A, OB, O C, Fig. 6, and let the applied field be parallel to O A. The component of the external field along O C would then be $H_o \cos \theta$, where θ denoted the angle between O A and O C, so that whilst the applied field would accelerate or retard electrons spinning about the axes O A by $\frac{H_o e}{m}$, the corresponding acceleration or retardation for O C would be $\frac{H_o \cos \theta e}{m}$. This showed why the displacement for all the lines was not of equal magnitude, which was a difficulty in

some theories which had been put forward to explain the Zeeman effect, as they gave the change of frequency in all cases simply as $\frac{H_0 e}{m}$.

To illustrate the Zeeman effect, the lecturer passed polarised light through a salted flame placed between the poles of an electro-magnet thence through a nicol prism, and on to a screen. By rotating the nicol the light on the screen was extinguished, but on then exciting the magnet the spot of light reappeared, indicating that the magnetic force had altered the frequency of the sodium light.

He also exhibited a model which, from the mathematical point of view, corresponded, he said, very closely to the motion of an electron in a magnetic field. In traversing a magnetic field such a particle was subject, he said, to a force at right angles both to the field and to the direction of its motion. The model consisted of a conical pendulum, the bob of which was a gyroscope. With the gyroscope not spinning, the periodicity of the pendulum had a certain value, which was, it was

Fig.6.

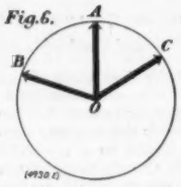
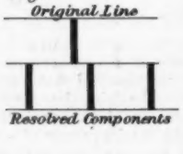


Fig.7.



shown, the same in whichever direction the pendulum moved. When, however, the gyroscope was spun, the rate of rotation of the conical pendulum was greater than the normal if it moved in one direction, and less than the normal if the direction were reversed. The forces acting on the spinning gyroscope whilst the pendulum rotated were, the lecturer said, of the same character as those to which an electron was subjected in traversing a magnetic field.

Continuing, the speaker said that within the last two years Stark had discovered another effect produced when the spectral lines were emitted in an electric field. It was difficult to establish a strong electric field in most of such discharge-tubes as were used for spectroscopic work. Stark had, however, succeeded by placing close behind the cathode a perforated plate, the interspace between the two being small compared with the "dark" space of the tube. Connecting up the cathode and the plate, with the opposite poles of a battery, a very intense field was produced between the two, which it was found possible to carry to thousands of volts per centimetre without causing a discharge.

In these conditions Stark noted that certain of the hydrogen and helium lines were affected, being split up in a fashion somewhat analogous to, but by no means identical with, that observed in the case of the Zeeman effect. For example, a line was divided into a triplet, as indicated in Fig. 7; but not one of the three components was quite in the same position as the original line. The components were, moreover, polarised in some cases in a plane at right angles to the electric force, and in others in a plane parallel to this force. The effect was, however, by no means so common as the Zeeman effect, and was of a very irregular character. Sometimes the whole of the components produced lay to the one side of the original line, and in many more cases the effect was altogether absent. In the speaker's opinion, the phenomenon had more to do with the nature of the atom concerned than with the character of the vibrators responsible for the emission of the light.

THE LATE SIR COLIN CAMPBELL SCOTT-MONCRIEFF.

WE regret to have to record the death, which occurred on Thursday, the 6th inst., at his residence, Cheyne-walk, Chelsea, of Sir Colin Campbell Scott-Moncrieff, K.C.S.I., K.C.M.G, LL.D. (Edinburgh), whose name will ever be associated with the transformation of Egypt under British auspices from a bankrupt Oriental State into a thriving country, the home of a prosperous peasantry. Sir Colin was born in Scotland, in August, 1836, and was the sixth son of the late Robert Scott-Moncrieff. He was educated at the Edinburgh Academy and at the Honourable East India Company's Military College, Addiscombe. He was appointed second lieutenant of the Bengal Engineers in 1856, and whilst serving in India he was engaged in the suppression of the Indian Mutiny. During his stay in India he was also engaged in the Public Works Department for about nine years. For six months of the time he was at the Barrack Department in Oudh, where he helped to restore the barracks wrecked during the Mutiny; then for three years he acted as Assistant Principal at the Thomason Civil Engineering College, Roorkee; being finally, and for five years, on the works of the Eastern and Western Jumna Canals. For a period he acted also as President of the Famine Commission in Mysore, and his experience in this connection led him to deal actively with the work of irrigation in India, with a view to minimising the famine scourge. On his return from India, in the late 'sixties of last century, he reported for the Government upon irrigation works in France and Spain, and in 1868 he published a book on the subject, entitled "Irrigation in Southern Europe." He retired from the Army with the rank of colonel in 1883, and was appointed Under-Secretary of State for Public Works in Cairo in the same year, a position which he retained until 1892.

When Colonel Scott-Moncrieff was appointed to the Cairo Public Works, the whole of the labour on the earthworks of Egypt was forced labour, and a very short time after taking up his appointment he endeavoured to replace this by contract work. He gradually succeeded, and, according to Sir William Willcocks, the forced labour for the maintenance of earthworks was finally abolished in December, 1889, this being "one of the creditable performances of the British occupation of the country." An idea of the difficulties which ruled in the early 'eighties of last century in regard to the construction and maintenance of public works in Egypt is gathered from a paper read in the summer of 1884 before the Institution of Civil Engineers by Mr. William Anderson. In summer, between May and August, during low Nile, many canals became quite dry for want of cleaning and maintaining at the required depth, and thousands of acres of summer crops of cotton and rice perished for want of water. Even when the canals were cleaned out the water was still below the land level, and every drop required for irrigation had to be raised by imperfect "sakieha" and small steam-pumps. Means of communication were so defective that Alexandria could not hope to compete in export produce. A step in the right direction, said Mr. William Anderson, was the appointment of Colonel Scott-Moncrieff, who had earned a high reputation in India, to the post of Under-Secretary of State for Public Works. Unfortunately, long neglect and mismanagement had rendered large expenditure necessary, and that very neglect and mismangement had crippled the revenue. Moreover, Colonel Scott-Moncrieff's appointment coincided with changes in the Egyptian Ministry, and he was compelled for many reasons to curtail his budget at the expense of many reforms.

After preliminary regulation work on the Delta carried out in the 'thirties and 'forties of last century by French engineers, among whom was Linant Pasha (M. Linant de Bellefonds), another French engineer, Mougel Bey, recommended and commenced the construction of a barrage on the Rosetta and on the Damietta branches of the Nile. In 1853, Mougel Bey was dismissed by the Viceroy, Abbas Pasha, who found that operations were not proceeding with sufficient rapidity, and his work was taken up by an Egyptian, Mazhar Bey, who completed it. These barrages appear to have been unsound, notably in their substructure, and never to have acted satisfactorily. When Colonel Scott-Moncrieff arrived in Egypt, in 1883, he endeavoured to utilise them. Dealing with this point in his paper above referred to, Mr. William Anderson says that he (Colonel Scott-Moncrieff) determined to make an attempt to raise the waters of the Nile by means of the barrages in question; they were being strengthened in a manner which, he expected, would enable them to perform the office for which they were designed, but he (Colonel Scott-Moncrieff) was quite prepared for a failure. The work of repairing and strengthening the two barrages was, however, carried to a successful issue by Colonel Scott-Moncrieff and the other British engineers who succeeded him. Dealing with his work in this connection in a preface, dated September 1, 1892, to the book on "The Fayûm and Lake Mœris," by Major R. H. Brown, Colonel Scott-Moncrieff stated the following:—"During the last nine years, it has fallen to the honourable lot of a small band of English engineers, most of them trained in India, to effect a revolution in the irrigation system of old Egypt, and thereby materially to improve the wealth and agricultural prosperity of the country. . . . We had the happy fortune to find things at their lowest ebb. We could hardly make a change without making an improvement. In all these improvements Major Robert Hanbury Brown, R.E., has from the first occupied a prominent place . . . It has fallen to Major Brown to help to restore the Fayûm. . . . He is not the first author on the subject. Learned Germans and brilliant Frenchmen have already written on the Fayûm. Major Brown pretends neither to the learning of the one nor to the brilliancy of the latter, but he has what neither one nor the other ever had, an accurate knowledge of the levels of the country. This information is quite indispensable to the hydraulic engineer, and it is strange that that distinguished Frenchman, M. Linant de Bellefonds, who devoted so many years to the physical improvement of Egypt, should have been evidently without it."

In his work on "The Binding of the Nile," and with reference to the Delta barrage, the Hon. Sidney Peel expressed the opinion that "it would have been far easier to rebuild the whole thing from the beginning, but at the time the necessary funds were not forthcoming. The British engineers had to take the old structure with all its imperfections and screw it up to work as it was. The country could not afford to cut off the summer water supply of the Delta while the repairs were in progress. The cotton crop had always to be thought of. And the period of the year during which the summer canals required to be supplied was the only period during which work could be done, for, once the flood came down, all operations were at an end. It is the glory of the said engineers that, working under these conditions and with untrained workmen, they succeeded in their task." We are glad to add the following, written by the same author:—"Sir Colin Scott-Moncrieff discovered Mougel Bey living in obscurity and oblivion, weighed down by poverty and neglect. It was owing to his intercession that the poor man was rescued from want, and, by means of a pension granted by the Egyptian Government, enabled to spend his remaining days in comfort and honour. Both nations are entitled to be proud of this act of poetic justice, which added a lustre of its own to the glory of the completed barrage."

Our present obituary notice on Sir Colin Scott-Moncrieff, as will be seen, is largely made up of quotations from other engineers. Apart from his book on "Irrigation in Southern Europe," and numerous technical reports to the Egyptian Government on his work for regulating the flow of the Nile, we do not find that he gave to the public a relation of his activities. He was elected an Associate of the Institution of Civil Engineers in 1868, but does not appear to have contributed to the Proceedings of that Institution. We must ask our readers to allow us one final quotation, since it affords an excellent illustration of the man and his work. In his book on "Modern Egypt" the Earl of Cromer wrote the following:—"Previous to the British occupation, the Public Works Department had been mainly in French hands. In 1883 it was resolved to appoint a British Under-Secretary to this Department, and to bring a staff of British officials from India to superintend the improvements in the canalisation of the country. Sir Colin Scott-Moncrieff was named Under-Secretary. The selection was a most happy one. Apart from his very remarkable technical attainments, Sir Colin Scott-Moncrieff was a man of the highest character. The most prejudiced Pasha respected qualities which were so dissimilar to any which he himself possessed. The most venomous journalist paused before he threw his political vitriol over a character so transparently honest. No Englishman employed in the Egyptian service during the early days of the occupation did more to make the name of England respected than Sir Colin Scott-Moncrieff, who, by the way, is not an Englishman, but one of that race which so frequently succeeds in foreign parts by virtue of its sterling good qualities. Sir Colin Scott-Moncrieff comes from well north of the Tweed."

Colonel Scott-Moncrieff remained in Egypt until 1892, and during his stay there he reported extensively to the Egyptian Government upon the work required for a careful irrigation of the arable land

of the whole country, quite apart from his work on the barrages above referred to. He returned to Great Britain in that same year, and was appointed Under Secretary for Scotland, a position which he held until 1902. He was President of the Indian Irrigation Commission from 1901 to 1903.

Colonel Scott-Moncrieff was appointed Companion of the Order of the Star of India in 1878, was created Knight Commander of St. Michael and St. George in 1887, and Knight Commander of the Star of India in 1903.

THE INSTITUTION OF NAVAL ARCHITECTS.

THE Institution of Naval Architects opened its spring meeting in the hall of the Royal Society of Arts on Wednesday last, the 12th inst., at 11.30 A.M., the Marquis of Bristol, the retiring President, occupying the chair. The meeting opened with the reading of the annual report of the Council for 1915, of which the following is a summary :—

THE ANNUAL REPORT.

The report first stated that, notwithstanding the continuance of the war, it has been considered expedient to hold the annual meetings in the same manner as last spring, so as not to break the continuity of a long series of years. The war had naturally had some detrimental effect upon the roll of membership, and especially upon the number of new candidates for election ; but the losses through deaths and resignations (apart from the suspension of alien enemy members) had not been more numerous than might reasonably have been expected. The membership for 1915 was made up as follows :—Honorary members, 16 ; members, 1164 ; associate members, 301 ; associates, 459 ; students, 152 ; total, 2092. Most of the professional members of the Institution were engaged upon work either directly or indirectly connected with the war, while among the associates were a large number of officers in the Royal Navy, the Royal Naval Reserve, or the Royal Naval Volunteers, all actively engaged in the war service of the country. Many of the younger members and students had obtained commissions in the land forces of the Empire, or were serving afloat in various capacities. The five-year term of office of the Marquis of Bristol as President of the Institution having come to an end with the close of the past session, the Council had invited, and had been fortunate in securing, the acceptance of the Earl of Durham, K.G., G.C.V.O., to succeed Lord Bristol. The Council desired to record their high appreciation of the great services which Lord Bristol has rendered to the Institution during his term of office.

Under Bye-Law 11 the Council have elected Sir Philip Watts, K.C.B., Engineer-Vice-Admiral Sir John Durston, K.C.B., Admiral Sir Henry Jackson, K.C.B., Mr. H. J. Cornish, Mr. R. H. Humphrys, and Mr. J. T. Milton, Honorary Vice-Presidents of the Institution.

The losses by death during the past year included the Earl of Glasgow, G.C.M.G., who held the Presidency of the Institution with much distinction for seven years ; Sir Nathaniel Barnaby, K.C.B., Honorary Vice-President, one of the founders of the Institution, who had been closely identified with its development for over half a century ; Sir Andrew Noble, Bart., Hon. Vice-President ; Mr. Henry Morgan, Hon. Vice-President, formerly Hon. Treasurer, and an original member of the Institution ; Professor V. B. Lewes, Honorary Vice-President ; Mr. E. C. Carnt, Member of Council ; Mr. Sydney Young, one of the few remaining original members of the Institution ; and Mr. J. B. Herreshoff, the well-known American yacht-designer. The following had lost their lives on active service :—Major H. R. Chapman, Captain W. M. Macmillan, members ; Lieutenant T. L. Bainbridge, Engineer-Lieutenant William Black, Mr. George Jackson, associate members ; and Mr. Roy M. Fernie, student.

The President of the Board of Trade has appointed Committees to consider the position of certain important British industries after the war. On the Committee dealing with the shipping and shipbuilding industries the following members of the Institution have been appointed:—Sir A. A. Booth, Bart. (Chairman), Sir Archibald Denny, Bart., Mr. W. S. Abell, M.Eng., and Mr. James Readhead. The Institution of Naval Architects Scholarship had been awarded to Mr. T. S. D. Collins, of Pembroke Dockyard, who is following the course at the Royal Naval College, Greenwich. A donation of 100*l.* to the Scholarship Funds of the Institution had been made by the Earl of Durham, K.G. (President-Elect). The Annual Gold Medal of the Institution for the past year had been awarded to Mr. A. W. Johns, R.C.N.C., for his paper on "A Comparison between the Results of Propeller Experiments in Air and Water ;" and the Premium to Mr. J. L. Kent for his paper on "Further Model Experiments on the Resistance of Mercantile Ship Forms." The Secretary (Mr. R. W. Dana) has, with the consent of the Council, given his services since last August as secretary to the department which is under the direction of Mr. Charles Ellis (Honorary Treasurer) at the Ministry of Munitions.

PRESENTATION TO THE MARQUIS OF BRISTOL.

Sir Archibald Denny, after the reading of the report of Council, which was carried unanimously, stated that a great honour had been conferred upon him by his being selected to thank the Marquis of Bristol for the great service he had rendered the Institution by acting as their President during the last five years. He had had a most distinguished career as a British naval officer, retiring as an Admiral after a service of 34 years. He had won the Beaufort test early in his career, and when later he was passed as gunner, he had received a letter from the Admiralty congratulating him upon having received the record number of marks. In the same year as he retired from the Navy, 1911, he was elected as their President, so that he continued to serve his country for another five years. He had presided over the jubilee meeting of 1911, when naval architects from all over the world were present, and the Institution owed a great debt of gratitude to Lady Bristol for the very kind way in which she had acted as hostess on that occasion and on the occasion of the summer meetings. The Council alone could know fully what was the extent of Lord Bristol's services to them, but the members would not fail to have noticed that his attendance at the meetings had always been constant and that he seldom had given a chance to any vice-president to occupy the chair. His presidential addresses had always been delivered quite openly, without fear of any possible consequences. The Council took that opportunity of presenting to him, Lord Bristol, on its behalf and on that of all the members, a framed water-colour sketch by Gribble, giving a short address and the signature of every Member of Council. He (Sir Archibald) asked Lord Bristol to accept it with the Institution's sincere thanks, and with the expression of the hope that he and Lady Bristol would be spared many years.

[The address stated that it was presented "as a mark of the appreciation of the great services which he had rendered to the Institution during his period of office as President."]

Lord Bristol, in responding, said he was grieved that his more intimate connection with the Institution had come to an end ; it had been a most pleasant connection, and in future he would have to seek other ways still to serve his country. He could not thank them too much for the very kind way in which Sir Archibald Denny had presented on their behalf the picture referred to. Anything coming from the artist Gribble was sure to be good. He (Lord Bristol) had in his possession a sketch drawn by him in five minutes, depicting a destroyer, which afforded an illustration of what the Fleet could do for the protection of all we held dear from a foe which does not stick to honourable means of carrying on a fight. May our own Navy still continue as he could say it had done since he joined it in 1877. The Institution, which had honoured him five years ago in appointing him its President, was a microcosm of the whole country, and, he added, "Would to God that the Government, who have such institutions as this grovelling at their feet to help, would take advantage of them and put their whole back into the work which has to be done in order that we may, as we shall, come out triumphantly at the end of this great struggle."

Sir Archibald had stated that he (Lord Bristol) always spoke what he thought ; he hoped he always would. Sometimes the terms he had used in regard to what the Government should do did not commend themselves to all his hearers ; he had spoken, among other things, of what an aerial fleet should do to meet the enemy, and in one instance Admiral Noel had said that a speech of his was a rather bellicose speech. But he (Lord Bristol) remained an unrepentant sinner. He was first and foremost an Englishman, and if anyone attacked this country he would do absolutely all that was in his power to uphold this country. He laid great hopes upon the Institution. What it had done in the past was so much to the good, it would continue to prosper, and with its aid this nation would remain the premier nation upon the ocean.

He congratulated the Institution for having been so fortunate as to obtain the Earl of Durham's acceptance of the presidency. The Earl of Durham was a man of the world, who had seen life and who knew how to use it. He had under his control wealth, and men working under him, also large mining interests. He was on good terms with all his employees, and no better test than that could be found. He did not belong to the Naval Service, but he had a brother who at a time of great national stress had used to the fullest advantage the means at his disposal : he had taken the guns to Ladysmith and had saved the situation. He was glad His Majesty had honoured Lord Durham recently by the bestowal of the Order of the Garter, and was pleased to introduce him to the meeting as the President of the Institution from that day forward.

THE OFFICE BEARERS.

The Earl of Durham then took the chair, and after the names of the new Members of Council and of the new members of the Institution had been read by the Secretary, he presented the annual Gold Medal to Mr. A. W. Johns and the Premium to Mr. J. L. Kent, for their work already referred to.

The new Vice-Presidents elected were : Mr. Thomas Bell, Engineer-Rear-Admiral G. G. Goodwin, R.N., and Messrs. J. Foster King, Andrew Laing, E. H. Tennyson D'Eyncourt, C.B., and W. H. Whiting, C.B. ; the Members of Council re-elected or newly elected were : Sir James Williamson, C.B., and Messrs. W. D. Archer, R. R. Bevis, James Brown, P. T. Caird, P. A. Hillhouse, B.Sc., W. W. Marriner, D. B. Morison, A. W. Sampson, R. L. Scott, John Smith, C. E. Stromeyer, J. E. Thornycroft, W. Weir ; and as Associate Members of Council: the Marquis of Graham, C.B., C.V.O., Sir Alfred A. Booth, Bart., and Mr. J. M. Falkner.

THE EARL OF DURHAM'S ADDRESS.

The Earl of Durham then said that although the members would not expect him to deliver any formal address at this meeting, he could not let the occasion pass without expressing his full appreciation of the honour they had done him in selecting him for their President. It was certainly difficult to act as a successor to Lord Bristol, but if a good will went to make a good President, he felt he would be one, and he trusted they would be lenient in regard to his shortcomings. He had an excellent remembrance of the Newcastle meeting of 1914, and he felt he could rely upon the kind consideration of the members. He was very glad that notwithstanding the war, the Institution had decided to hold its meetings as usual. It was a characteristic of the British spirit. It was impossible to disguise the fact that the situation had greatly altered since those days, two years ago, when the Institution met in the north. At the present time one paramount duty was before the whole nation, and that was vigorously to prosecute the war until a satisfactory solution was reached. He remembered that among the discussions at the Newcastle meeting there had been one on submarine warfare ; the problem then was one of theory and conjecture, but submarine warfare had since entered into the realm of actualities. The papers on the subject which had then been read were well timed and were almost of a prophetic nature. The fact that this and other naval subjects were being continuously discussed afforded a proof that we were not satisfied to rest upon our oars, but that we were constantly alive to all new methods. Our naval architects had no better pride than to turn out everything destined for the Navy of the best possible quality, and in this we were reaping the reward of years' of good work. We all admired our sailors ; we always trusted them, for we fully knew that they never would fail us within the limits of human possibilities. It was impossible for us to express to the full the gratitude we felt to our naval men, mercantile men, naval volunteers and fishermen ; theirs was one long story of heroism, skill and

dogged endurance, and when the end of the conflict came he felt sure that the Institution of Naval Architects would also be able to claim having done its share in the work. It would then be able to return to its ordinary peace-time avocations, and he hoped he would be able to share in the congratulations which the Institution would then receive. He expressed again his thanks to the members for his nomination; when no higher duties called him away they could count upon him, and he knew he could count upon them.

The Load-Lines of Merchant Ships.

The meeting then passed to the consideration of Sir Philip Watts's paper on "The Load-Lines of Merchant Ships; Work of the Load-Line Committee (1915)," which, at the request of the author, was read in abstract by the Secretary. We reproduce it in full on page 348.

The second paper, on "Some Questions in Connection with the Work of the Load-Line Committee," by Mr. W. S. Abell, M.Eng., was then read in abstract by Sir William E. Smith, in the enforced absence of the author owing to illness. We reproduce it also in full on page 361.

The two papers were taken together for discussion. This was opened by Sir J. H. Biles, who stated that the paper by the Load-Line Committee was the result of a good deal of honest work. It took a broad view of the whole situation in regard to freeboard; it was most interesting, and brought us well up to date in the matter. The question of freeboard was a very indefinite one at one time, as some members present could remember; but it had been dealt with by successive committees and workers, who had now finally brought it to a point which was satisfactory to naval architects. With reference to the paper by Mr. W. S. Abell, he regretted that the author was unable to attend the meeting. The question of the strength of ships was one which lay at the root of the naval architects' and shipbuilders' work. His attempt to give a suitable standard of structural strength was admirable. In the past naval architects had been largely guided by the rules set down by the registration societies, and Mr. Abell's method would imply that we should adopt the scantlings of the registration societies as being satisfactory. This obviously led to doubts in the minds of those who did not always agree with registration societies in the matter. The difference between the practical method of accepting registration scantlings and the scientific one was that in the latter an attempt was made to obtain the bending moment coming on the ship; this was dependent upon the wave the ship had to meet, and on the distribution of the load in the ship. Both varied. Some people based the calculation upon a standard wave and a homogeneous cargo. What was to be done was obviously to provide good material and sufficient of it to resist stress. The distribution of longitudinal stress varied as the bending moment. It could be calculated and the variations in the bending moment due to the distribution of weights could be found. But the distribution of the wave surface was not known. Mr. Abell had proposed to substitute for the formula $\frac{p}{y} = \frac{M}{I}$ the one $\frac{I}{y} = \frac{M}{P}$. It was clear that M would vary at sea according to the loading of the ship. The assumption that $\frac{I}{y}$ was satisfactory involved that p varied according to M. The $\frac{I}{y}$ might be well satisfied and yet a high stress be upon the material. One had to assume that the material was sufficiently strong to meet all variations. The fundamental difference between what Sir J. H. Biles called the "older method" and the one put forward by Mr. Abell was that no attempt was made by the latter to take into account variations in the forms of the ship; the same $\frac{I}{y}$ was used for fine-lined ships and for those of the cargo type. The method put aside the scientific view of the question; this might be due to the fact that the Committee consisted largely of members of registration societies, rather than of independent scientific men. Beyond that he had nothing but admiration for the paper. Mr. Abell had dealt with the question of transverse strength, which was difficult, in a way which, with our present knowledge, could not have been improved upon.

Sir William E. Smith here interposed, with reference to the constitution of the Committee, that it was true a large number of its members were members of registration societies. The load-line problem involved a large number of questions to be considered with a view to assisting the Board of Trade, and it was necessary that the points dealt with should be put forward as being usable by the registration societies. Sir William then read short abstracts from an official report of the Committee on the Determination of Strength, adding that they had found Mr. Abell's formula to give results practically similar to those obtained at the Admiralty.

Sir Archibald Denny, who followed, said his position in the matter was, perhaps, a little peculiar, since he happened to be chairman of the Bulkhead Committee. He would add that when the Load-Line Committee was first constituted, and for many months after, Mr. Abell was a Professor, and its work was practically completed before he was appointed at Lloyd's; at the outset he was, therefore, an independent naval architect. As for himself, he was originally a very active member on the registration societies, but now he reckoned himself as being quite an independent naval architect. He complimented Sir Philip Watts and Mr. W. S. Abell upon having completed their labours, and he complimented also the whole Committee upon the good work they had done. Sir Philip's historical description of the freeboard question was of the highest value. The revision of the Freeboard Tables was strongly pressed by the 1898 Committee. The skill of the chairman of the Load-Line Committee had been shown by the fact that a unanimous report had been arrived at. He joined with Sir J. H. Biles in hoping that the new Council would devote funds to solving the knotty point as to the relative strength of full and fine vessels. All ships were one of two large classes, either flush decked or having erections, and it was evident that, apart from the question of stability and comfort on board, if the ship were so constructed that no water could enter, the question of freeboard did not come in. Submarines, for example, navigated safely, whilst as to comfort that could not be said to be a feature of that craft. He was sorry that Mr. W. S. Abell, who had been working for so many years at the problem, could not be present and receive the praise that was his due.

Mr. P. A. Hillhouse, who asked for explanations in regard to several of Mr. W. S. Abell's formulæ and statements, was followed by Mr. J. Foster King, who said that the Committee had torn down the veil of secrecy, giving methods and reasons, and had stated how their results had been arrived at. The real question being safety, comfort being only relative, they had done all they could to conserve the British mercantile marine.

Professor Welch expressed the view that the difference of opinion which existed was one rather of form, of words rather than of substance. When, for example, Mr. W. S. Abell stated in one part of his paper that "... the strength should vary as the draught d," the word "strength," which a speaker had objected to, was perhaps not the exact word to use. The real standard strength of a structure was indicated by the ratio which the actual stress on the material bore to the strength of the material, and what Mr. Abell had in view was that $\frac{I}{y}$ should vary as the draught d. Mr. Abell had said that with increased size the shearing stress also increased; he (Professor Welch) had found that very approximately true.

Sir Philip Watts did not agree with the criticism of Sir J. H. Biles, and he hoped he would change his mind when he looked further into the paper. Mr. W. S. Abell was to be congratulated upon his work, and he (Sir Philip) thought it might be found suitable for international purposes. Calculations were required, but experience also came in and must be used for comparative purposes. The merit of Mr. Abell's work lay largely in the combination of the results of mathematical deduction with those derived from practical experience. The author's method would be of very great service in the consideration of new ships.

On the motion of the Chairman, the authors were awarded a hearty vote of thanks for their contributions.

Skin Friction.

The first paper to be taken at the afternoon meeting was entitled "The Laws of Skin Friction of a Fluid in Stream-Line and in Turbulent Motion along a Solid of Great Length." In this paper the author, Professor C. H. Lees, of the East London College, has attempted in the first place to establish a connection between the skin friction of a pipe and that on the hull of a vessel, and, secondly, has advanced reasons for believing that the relative resistance of two different forms is in some cases much the same whether the fluid motion be of a stream-line character or whether it is turbulent. For stream-line motion he has been able to solve in some cases the hydro-dynamic equations which express the relative resistance of bodies of different forms. Froude had, the author stated, adopted a formula for the skin friction of the form $F = f A V^n$, where f was a constant depending on the nature of the surface, the wetted area of which was denoted by A, and the velocity of motion through the water by V. This formula had been applied to cover cases ranging from planks 19 in. wide up to Atlantic liners of the largest size. A similar law had, the author stated, been used to express the friction of pipes, but it was found that, to agree with experiment, n must be increased at high values of V. The author had, however, found that all experiments on pipe friction, whether made with air or water, could be expressed as a "two-power" formula. Thus, denoting by A the area of the surface, by ρ the density of the fluid, and by v its velocity, then, if ν were the kinematic viscosity, the resistance was:—

$$F = A \rho v^2 \left[a + b \left(\frac{\nu}{d v} \right)^n \right],$$

with the values $a = 0.0009$, $b = 0.0765$, and $n = 0.35$.

The term in brackets was independent of the units used, provided these were consistent *inter se*. Thus, if the viscosity were expressed in dynes per sq. cm., the velocity must be taken in centimetres per second and the diameter in centimetres. The expression held for all fluids, provided that the quantity $\frac{\nu}{d v}$ were greater than 3000. A closer approach to the problem of ship resistance was afforded by the resistance offered by a long body fixed in a pipe to the fluid flowing past it. The theory of stream-line motion showed that in this case the resistance of a body of elliptical section was equal to that of a body of circular section when twice the diameter of the circle was equal to the sum of the principal axes of the ellipse. With a very elongated ellipse which would be approximately equivalent to a thin plank, the diameter of the equivalent cylinder was half the width of the plank. Hence for equal wetted perimeters the plank resistance was 0.785 that of a cylinder. Making allowance for this, a comparison with Froude's experiments on the frictional resistance of planks showed a good agreement with that calculated from the author's formula, which for water, taking v in centimetres, reduced to

$$F = v^2 \left\{ 2.10 + 12.2 \left(\frac{1}{v} \right)^{0.35} \right\} \text{c.g.s. units,}$$

v being expressed in centimetres per second. The above theoretical result, the author pointed out, was in accord with Kent and Baker's discovery that the value of f in Froude's formula was 28 per cent. more for a circular section than for a flat board.

Another deduction from the formula was that if approximate formulæ of the type $F = f A v^n$ be used, the value of n is less for the model than for the full-sized ship. In the latter it becomes nearly 2 for speeds of 26 knots per hour. It further follows from the theory that whilst temperature changes have a material effect upon the resistance of a model, that of a full-sized ship is practically unaffected. Another conclusion arrived at was that the increase of skin friction due to bilge-keels was less than would be calculated on the usual assumption that the increase was directly proportional to the additional wetted surface, a result which received some confirmation from Froude's experiments on the Greyhound. Moreover, if the surface were increased in the one case by constructing a channel in the skin, and in another by adding a bilge-keel of equal area, the resistance offered by the latter would be considerably the greater.

It was decided to postpone the discussion on Professor Lees' paper until Mr. G. S. Baker's paper on "Skin-Friction Resistance of Ships and Our Useful Knowledge of the Subject" had been read. In this paper Mr. Baker stated that whilst

the various experiments made on the friction of smooth planks were in fair accord, the experiments on very short lengths of plank showed discrepancies. Thus for a plank 2 ft. long, coated in the one case with tinfoil, and in the other with paraffin, the value of n in Froude's formula was 1.95 for the paraffin and 2.16 for the tinfoil. The two surfaces to the touch were equally smooth, and with planks 20 ft. long the value of n was the same for both. He attributed the discrepancy to a change in the character of the motion, equivalent to that experienced in pipe experiments, when the velocity passed through its critical value. Hence he felt justified in ignoring results obtained with very short lengths of plank. One deduction to be drawn from the foregoing was that in ship-model experiments errors might be feared if the value of V L was too low. The minimum limit was V L = 40, or 240 ft. per minute for a 10-ft. model. Fewer experiments were available with solid surfaces. Such results as were to be found showed that at low speeds full-bodied models had a resistance higher than that of a plank by some 5 to 15 per cent The assumptions usually made in calculating skin friction were:—

1. That the resistances of a solid body and of a plank of the same wetted area and length were sensibly the same.

2. That the resistance of long planks at high speeds could be calculated from that of short planks by Froude's formula.

3. That the quality of a ship's surface was the same as that of a smooth plank.

It appeared, however, that (1) was only sufficiently exact in the case of long models, and that the body form had an increasing effect as the prismatic coefficient rose. Indeed, if the theoretical stream velocities around any solid form were calculated, it appeared that the mean value of the rubbing velocity was generally greater than that of the form itself. With regard to assumption (2), the law of dynamic similarity indicated that the actual skin friction of ships should be less than if calculated on this assumption. In the case of a ship 600 ft. long, running at 20 knots, the old method gave 10,300 horse-power as the power absorbed, whilst from the law of dynamic similarity 9000 horse-power was derived. The Greyhound experiments, it was true, showed a loss in skin friction 20 per cent. more than calculated by Froude, but the difference was attributed to the roughness of the bottom. As for assumption (3), all reasonably smooth models gave equivalent results, but in practice a ship's hull surface was broken up by the heads of the rivets and the butts of the plating, which must increase the friction. Experiments had been made at the National Physical Laboratory with models having plate edges to scale, representing $\frac{3}{4}$-in. plates on a 400-ft. ship. The increase of resistance was 3.7 per cent. In another series of tests the increase was 10.3 per cent. with a prismatic coefficient of 0.63, whilst with a prismatic coefficient of 0.82 the increase was 8 per cent. at low speeds and 12 per cent. at high. In this case removing the butts over the first one-eighth of the length reduced the figures to 4.8 per cent. at low speeds and to 7.2 per cent. at high ones. Tests of a Newcastle steamer showed an increase of 20 per cent. in the resistance after three months without docking. Tests made at the Washington Tank of a plate fouled by immersion showed an increase of 220 per cent. in its resistance as compared with that of a smooth plate. As growth is slow in cold water, the author suggested that coasting ships in these latitudes should be cleaned and painted in October or November, whilst a new coat about May or June would check adhesions during the warm weather.

To make tank experiments directly comparable with those on full-sized ships, the roughness of the model should be similar to that of the ship. Hence a 3-in weed growth on the ship would be represented on a scale of $\frac{1}{20}$ by a growth 0.15 in. long. Tests thus made, however, led to overestimates of the ship resistance.

The Secretary then read the following letter from Mr. R. E. Froude:—

> The fault which I find with this otherwise interesting and suggestive paper of Professor Lees is that it ignores a certain fundamental difference in *régime* which there is between the skin friction in a long pipe and that of a plane or body of whatever length travelling in open water. This difference has to do with what, in open water skin friction, is termed the frictional wake—a belt of water clothing the surface, and moving more or less with it, having been set in motion by the frictional force, which in turn it satisfies by the momentum of the speed which has been imparted to it. This belt of fluid, from the nature of the case, progressively increases in effective thickness, with increasing distance sternward from the leading end of the surface; and this progressive increase in thickness is necessarily accompanied by a corresponding decrease in the rate of shear in the fluid, and therefore also in the frictional force per unit of surface area.
>
> Now, in the first few diameters of length of a pipe leading, say, out of a cistern, there will exist a phenomenon of similar character to this; but in all pipe experiments on skin friction such portion of the pipe is carefully excluded from the region of observation, expressly in order to exclude the presence of any such phenomenon, and thereby to ensure that the rate of shear in the fluid and the concomitant frictional force per unit of surface area shall be uniform throughout the length of the pipe considered. Thus we have there a system of established and unchanging motion, with frictional force satisfied, not as in open water, by the imparting of momentum, of which in this case there is none, but by a uniform statical gradient of pressure along the pipe.
>
> In the mechanics of skin friction, everything obviously depends on the rate of shear in the fluid, and its distribution nominally to the frictional surface; and in respect of the conditions regulating these two factors there is for the above reasons every difference between the two contrasted phenomena of friction between pipe walls, on the one hand, and open water friction on the other. And, among other things, there is this specific difference in the upshot, that while in the pipe the rate of shear and concomitant friction per unit area depend on the speed and on the *diameter* of the pipe, in open waters these things depend on the speed and on the *length* of the surface.
>
> I do not wish to suggest that pipe skin friction observations can be of no assistance in the study of open-water skin friction. On the contrary—and that in virtue of the very peculiarities of the pipe skin friction phenomena above adverted to—it seems that pipe skin friction experiments afford special facilities for the empirical study of the main factor in the problem, namely, the relation of rate of fluid shear to concomitant shear stress, under various conditions of flow; and, as an instance of this, I would point to the pipe experiments described by Dr. Stanton in his Royal Society paper of June 29, 1911.* Once adequate knowledge on this head has been obtained, it does not seem in the nature of things impossible to apply such knowledge synthetically to the conditions of the open-water problem.

The discussion was opened by Mr. Barnaby, who expressed the view that experiments on the effect of skin roughness would be the most important that could be made at the present time. The propulsive coefficient of modern destroyers was distinctly lower than that of their predecessors. There was a tendency to attribute the whole of the defect to the use of high-speed propellers, but the speaker thought that it was, at any rate, partly due to the greatly increased roughness of surface which had followed the adoption of high tensile steel for the plating. In the old days rivets were flush with the surface; this was no longer practicable. There were regulations as to the amount of protrusion, but the limit fixed was a lower limit, to which it was impossible to adhere, so that the fulness of head was always greater than that specified, being thus always on the wrong side. He would suggest to Mr. Baker that an impression might be taken from the side of a destroyer, and a model of this made to scale, and its frictional resistance tested. He would not predict the result; yet, although he was told that a pimply golf-ball had its advantages, he was very certain that a pimply hull had none. With regard to Dr. Lees' paper, he was interested in the conclusion that temperature effects were nil in the case of actual ships. This accorded with his own experience, which was that, although a temperature effect could be observed in tank experiments, there was none perceptible in the behaviour of actual ships. He had also been struck by Dr. Lees' suggestion that, if the surface of a ship were constructed with a channel in it of the same area as that which would be offered by a bilge-keel, the skin friction would be less. In actual practice this had not been observed, the reason being perhaps that channels in hulls were only used to accommodate a propeller, and the relative speed of the water over the surfaces was accordingly increased.

Professor T. B. Abell, who spoke next, suggested that by determining total resistance curves for two models over a long range of speeds it should be possible to separate out the parts respectively due to wave-making and to skin friction, even if the exact law by which the latter varied were unknown, since the eddying resistances would follow the law of dynamic similarity. Possibly the equations involved might, in practice, be difficult to solve, but a mathematical colleague had informed him that the plan was sound theoretically. He would suggest that Mr. Baker's method of comparing the roughness of a model with that of a ship was only applicable to that proportion of the total resistance which was governed by the law of dynamic similarity, and did not apply when making corrections for skin friction by means of the usual formulæ.

Professor Dalby observed that many of the advances in the methematics of stream-line motions made use of in Professor Lees' paper were due to Professor Lees himself. Moreover, the latter had not merely worked out the mathematics, but had also shown how his results might be applied to the special problems of the naval architect. In future discussions of skin friction it would be impossible to neglect this paper of Professor Lees. He would ask that author if the index in his formula had in all cases the value 0.35. He would further ask him if he could add to the paper a table of kinematic viscosities expressed in engineers' units. So far as stream-line flow was concerned Professor Lees had effected a distinct advance; but, as stated in the paper, there was no mathematical theory applicable to the turbulent flow, with which they were mainly concerned. He would suggest, therefore, that great advantage would result from large-scale experiments on the towing resistance of ships. Why not take the Mauretania and set her to tow other selected vessels? The only difficulty was the expense, but in view of the value of the results the experiment would, he thought, be well worth while. It would settle in a large measure the question of ship resistance.

Sir William E. Smith thought that the papers showed a good combination of mathematics and practical common-sense, the conclusions being set out in such a way that practical men could deal with and use them. His own mathematics were insufficient for him to deal with Dr. Lees' paper, but that presented by Mr. Baker added to the already abundant evidence of the good work done at the Froude Tank. This had now been in existence some years, and an excellent report of valuable work had been sent in yearly to the Royal Society, and this year was no exception to the rule. Sir Alfred Yarrow did not like references made to what was owed him for the establishment of this tank. Apart from the work done there, however, our knowledge of the matters discussed that afternoon would have been much smaller than it actually was. He would ask all wealthy firms to assist in the work by devoting to it some of whatever surplus Mr. McKenna might spare to them. The tank had a very efficient staff, and Mr. Baker had proved a most able superintendent, skilled not merely in getting the work done, but in preventing this work from being merely filed away and pigeon-holed.

Sir Archibald Denny said that his experience was that a considerable "bump" in a ship form did not add to the resistance unless it was very "sudden." As for changes of temperature, he was inclined to believe that they did affect the resistance of full-sized ships, and it was his practice to correct for it.

In reply, Professor Lees said that he fully recognised the point advanced by Mr. Froude that the flow in pipes did not exactly correspond to that of a cylinder dragged through a fluid. In fact, he had had this in his mind throughout. His object in drawing a parallel between the two was meant mainly to be suggestive and to show naval architects that some connection between the two must exist which would be useful when properly determined, and would in that case be, moreover, exact. Mr. Froude had raised the point that the shape of the hull made no difference, but this conclusion was contradicted by Mr. Baker's results, which qualitatively, at any rate were in accord with the speaker's deductions. The theory he had worked out showed that the resistance of a surface when of circular form was $\frac{4}{\pi}$ times as great as that of an equal flat area. Mr. Baker's experiments showed that there was a difference in the two cases, and from the speaker's point of view this was very important. He was interested to learn from Mr. Barnaby that it was impossible to detect any effect of temperature on the resistance of actual ships. This, again, was in accord with what would have been anticipated from the speaker's formula. As to Professor Abell's suggestion that the skin-friction effect might be sorted out from curves of total resistances determined for two models, this was theoretically practicable. In fact, from the effi-

* Proceedings of the Royal Society of Architects, vol. lxxxv, page 368.

ciency curves of dynamos and motors, it was possible to deduce which of the losses varied with the first power of the current, and which followed the second power law. The difficulty in making a similar analysis of the total resistance curves of ship models lay in the near equality of the two powers of the velocity involved. The index 1.8 was so near to 2 that it would be impossible to place much dependence on the results. In reply to Professor Dalby he might say that the index was constant in his formula. He would be glad to add to his paper a table of kinematic viscosities expressed in engineer's units. As to the suggestion for further towing experiments, he had himself proposed that experiments of this kind should be made with submarines, thus getting rid of the resistances due to surface waves. Experiments of this kind would give a great deal of information, as nothing was now available between results observed with models 16 ft. long and those recorded with full-sized ships. The data obtainable on towing a submarine some 200 ft. long would therefore provide some interesting information. In concluding, he would like to congratulate Mr. Baker on his courage in publishing results showing that skin friction was not independent of hull form, when there was a general belief to the contrary,

Mr. Baker, in his reply, expressed his thanks for the many appreciative remarks on the work done at the Froude tank. As to Mr. Barnaby's suggestion to make a scale model of the actual surface of a destroyer, this would not be an easy matter. Full-sized rivet heads could be seen and handled, but when reduced to a scale of $\frac{1}{10}$ they became very small. He did not see his way to getting exact similarity, but the difficulty might be got over, and he would in that case be very glad to make the test. If the resistance of such surfaces followed the law of dynamic similarity, the view taken in his paper as to relative roughness of model and original was correct, but he could well imagine surfaces so rough that no law of resistance would apply. He understood that experiments on turbulent flow were in progress at the East London College, and he would ask Professor Lees if he could not add to his paper some statement of the results so far attained. There was, of course, no rational basis for the step taken in Professor Lees' paper from the stream-line flow to turbulent flow, so that experimental support would be of special value.

BILGE-KEELS.

A paper by Professor T. B. Abell, on "Experiments to Determine the Resistance of Bilge-Keels to Rolling," was next read. In this paper the author recalled the fact that the effect of bilge-keels in checking rolling was found to be far greater than was anticipated, as the result of Froude's experiments made with a submerged plate oscillated in a direction at right angles to its plane. The explanation of the discrepancy was, the author stated, first given by Sir Philip Watts, who expressed the view "that the excess of the resistance in the case of bilge-keels over that of a plane moving through water at right angles to the plane is doubtless mainly due to the moment of the pressure produced upon the hull of the ship in the vicinity of the bilge-keels; it will readily be seen that the effect of these pressures will depend upon their direction and position with regard to the axis about which the ship is rotating, and therefore upon the shape of the bottom." The object of the author's experiments was to clear up some of the phenomena involved. The experiments were made with a rectangular prism 6 in. square and 12 in. long, immersed in water with its axis vertical. This prism was hung by a $\frac{1}{8}$-in. rod from a tray having a trifilar suspension It was caused to oscillate about a vertical axis, and the rate of decrement of the swing observed under different conditions. By placing weights on the tray the forces producing vibration could be varied. A layer of planks above the prism, but slightly below the surface of the water, prevented the production of surface waves by the oscillations made. The tank was sufficiently large to prevent its boundaries having any very marked effect on the rate at which the energy of the oscillation was dissipated. The bilge-keels were secured to the corners of the prism, and provision was made for introducing into the water fine streams of coloured fluid, so that the nature of the motion in the immediate neighbourhood of the keels could be observed. The experiments made included (1) resistance experiments and (2) "period" experiments to determine changes of equivalent mass inertia. The experiments showed that the damping resistance could for large amplitude be expressed reasonably well by the relation

$$R = k\left[\frac{d\theta}{dt}\right]^2,$$

where R denotes the damping resistance and $\frac{d\theta}{dt}$ the angular velocity of the swing. It was found that the bilge-keels produced a resistance equal to five times that of the block without the keels. The second series of experiments showed that without the bilge-keels the apparent increase of mass was 28.5 per cent., whilst with the bilge-keels it was 72 per cent. The former figure had, since the writing of the paper, been confirmed by a theoretical investigation made by one of the author's colleagues, who had calculated the apparent increase of mass during the oscillations of the square prism as 27½ per cent.

The discussion was opened by Mr. Cannon, who suggested that it would have been better to start the experiments with a circular cylinder in place of with a square prism, as in that case practically the whole of the damping would be due to the keels. He quite appreciated the difficulty found by the author in making observations with the keels removed, as he had met with the same difficulty in experiments made at Glasgow University for Sir John Biles. He asked what was the size of the keels used, and had they sharp or rounded edges. He would observe that in ships the period only diminished with increasing amplitude, if the Gz curve was of appropriate shape. If the value of Gz increased more rapidly than sine θ, the period would be greater at large than at small angles of roll. He was not surprised that the apparent displacement due to the bilge-keels was as much as 72 per cent. In fact, if the true displacement of the prism were reduced to zero, the percentage would rise to infinity.

Mr. G. S. Baker, who followed, considered the author's a very ingenious way of separating out one portion of the work done in extinguishing the roll of a ship. It provided, in short, a means of separating out and studying the vortex motion, which went on behind a bilge-keel free from any disturbances due to wave formation. He considered the results very interesting.

Sir William E. Smith said that the paper described an experimental investigation made on a body entirely submerged, the object being a determination of the probable resistance of bilge-keels as applied to actual ships. Bilge-keels were put on to passenger and warships in order to check rolling, which was a serious problem in the case of warships forty years ago. A most useful check on rolling was the water-chamber introduced by Sir Philip Watts, which was very effective at small angles of roll, and when fitted greatly helped gunnery practice. Later on these chambers were abandoned in favour of bilge-keels. As ships continued to grow in size more and more, and weights were added further and further, from the centre line, designers began to doubt whether bilge-keels of practicable size could possibly be effective. None were accordingly provided for the Revenge in view of the large moment of inertia of the ship. An additional reason lay in the circumstance that the fitting of bilge-keels to a large ship reduced the number of docks into which she could be taken for repair in case of need. It was thought safe, therefore, to omit the bilge-keels. The experience gained on active service showed, however, that the ship did not behave as well as anticipated, and a close study of the bilge-keel was made accordingly. The experiments made on full-sized ships showed that the damping was far greater than the then theory had led them to expect, and further experiments were made to see how this came about. The speaker thought that Professor Abell's work marked a great step forward in the matter of making it easier to ascertain whether bilge-keels would be of some good in particular cases and not be merely a nuisance, and he trusted the study would be pursued.

Mr. Woollard, who spoke next, raised the question as to whether the suppression of surface waves would influence the results. On the usual theory, part of the damping was held to be due to the water thrown up to the surface by the action of the keels, and if none reached the surface it might be questioned whether the final result would be the same. He hoped the experiments would be continued, as they would not fail to throw valuable light on the rolling of ships.

Professor Abell, in reply, said that the keels fitted to his model were ½ in. deep. He had adopted the square form because this could be cut down to a circle later on. In his experiments made at small amplitudes much of the resistance noted was viscous resistance; but at large angles the resistance varied very accurately as the square of the angular velocity. He agreed that in actual ships the bilge-keels produced disturbances which reached the surface and travelled out as waves. In his experiments, however, he had thought it best to avoid complications of this kind and to test one point at a time.

AN EXPERIMENTAL TANK REPRODUCING WAVE MOTION.

A paper on this subject was down for reading by Colonel G. Russo, R.I.N., and in the absence of the author was taken as read. Sir John Biles announced, however, that cinematograph views showing the working of the tank would be exhibited on Thursday afternoon.

At the evening meeting on Wednesday the following papers were read:—

"A Brief Summary of the Present Position of the Marine Diesel Engine and its Possibilities," by Engineer-Lieutenant W. P. Sillince, R.N. (ret.); "On the Co-ordination of Propeller Results," by Mr. J. Denholm Young. "Note on Maximum Propulsive Efficiency of Screw Propellers," by T. C. Tobin.

On Thursday, April 13th, the following papers were taken:—

"Sub-Division of Merchant Vessels; Reports of the Bulkhead Committee, 1912–1915," by Sir Archibald Denny, Bart., LL.D.; "Strength of Watertight Bulkheads," by J. Foster King; "Some Effects of the Bulkhead Committee's Reports in Practice," by A. T. Wall; "Notes from a Collision Case," by John Reid; "Shipyard Cranes of the Rotterdam Dockyard Company," by M. G. de Gelder. We shall give a report of the discussion in a future issue, and reprint certain of the papers.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, March 29.

THE gigantic preparations now being made for an increased supply of munitions and munition material in the United States for next year's delivery in Europe go very far to contradict any anticipations of an early termination of the war. Recent inquiries from abroad called for some 500,000 tons of material and supplies; there is some delay in placing orders owing to rather extraordinary advances in prices because of uncertain future delivery. Among present inquiries from abroad are 10,000 railway cars, 500 locomotives, and 150,000 tons of rails. The present total of all foreign inquiries for wire and wire products total at least 800,000 tons, probably closer to 1,000,000 tons.

The latest pig-iron-buying movement has aggregated upwards of 500,000 tons, in which Southern furnaces liberally participated. The prediction appears in some quarters that average pig-iron quotations will in the not remote future reach 25 dols. a ton, and even higher possibilities are openly hinted at. Further advances have been made in cold-rolled strip, steel rivets, wire rods, tin-plates, skelp, shafting, and bolts and nuts. Early delivery plates have reached as high as 3½ to 4 cents. On account of such high prices there is a strong tendency to the use of concrete, which creates a demand for reinforcing-bars. Shipyards have quite recently succeeded in placing orders for 250,000 tons of plates and shapes, besides which there are about to be closed tentative inquiries for 20,000 tons steel for vessels. The entire steel market continues in a very strained condition, and further advances appear to be in sight.

Domestic demand is strong, but a great deal of material urgently wanted cannot be secured excepting under conditions as to delivery, which leaves the consuming interests in a more or less uncertain frame of mind. Intense activity prevails in steel-rail circles because of the determination of most of the larger railway systems to cover their next year's requirement at an early date. Rails are the only article on the list which have not been advanced, while prices on nearly all other products have been much more than doubled. The figures of rail orders placed during the past week or two run over 1,000,000 tons.

AMERICAN SHIPBUILDING.—At the commencement of February, this year, there were 230 steel mercantile vessels building, or under contract to be built, in private American shipyards. The geographical distribution of the new tonnage under construction may be given as follows:—Delaware River, 65 ships, 291,969 tons; Chesapeake Bay, 43 ships, 421,406 tons; Pacific Coast, 31 ships, 173,178 tons; the Great Lakes and sundry rivers, 64 ships, 141,163 tons; New England, 19 ships, 68,078 tons; and other districts, 8 ships, 4577 tons.

MULTIPLE-SPINDLE SENSITIVE DRILLS.

CONSTRUCTED BY MESSRS. ALFRED HERBERT, LIMITED, ENGINEERS, COVENTRY.

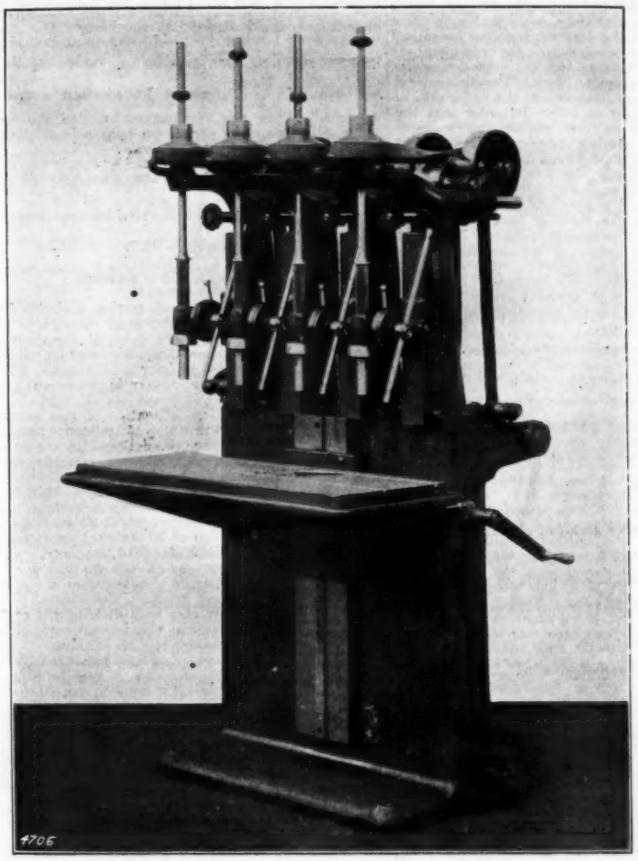


Fig. 1.

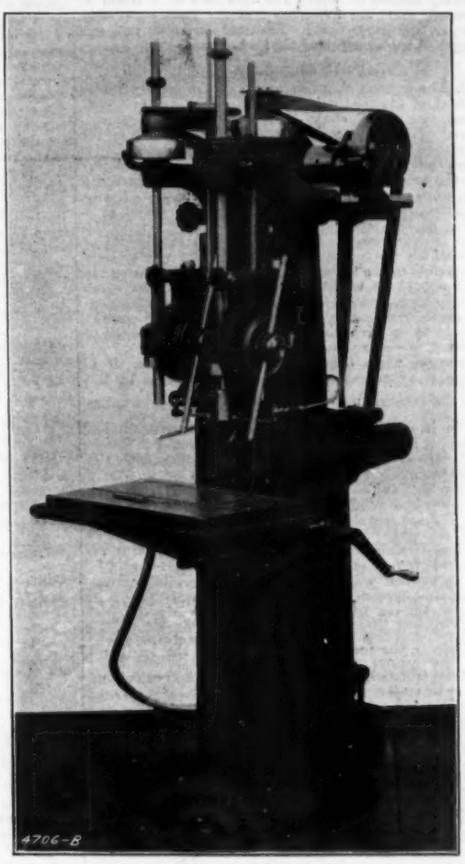


Fig. 2.

We illustrate above two examples of a line of multiple-spindle drills now being constructed by Messrs. Alfred Herbert, Limited, of Coventry. Fig. 1 shows a four-spindle machine with hand-feed, and Fig. 2 a two-spindle machine with a patented form of automatic feed, which will be described later. As will be seen, the spindles are each mounted on short columns bolted on to a substantial pedestal of box construction, having a wide base for bolting to the floor. The spindles, it will be noticed, are spaced wider apart than is usual in multiple-spindle drills, so as to give ample room for operating them, a feature which considerably facilitates rapid working. The table, which is mounted on a slide formed on the pedestal, is self-sustaining, and can be moved up and down by a rack and pinion operated by a crank-handle. Two planed T-slots are provided for clamping work or locating strips when jigs are used, and a suds channel is formed round the edge of the table for collecting the lubricant used in cutting. The machine illustrated in Fig. 2 shows this channel connected by a flexible metallic tube to the oil-pump reservoir placed behind the pedestal. Clogging of the passages by chips or dirt is rendered impossible by the firm's patented method of forming the channels.

The spindles are driven by belts from a counter-shaft at the back of the machine, the belts running over idler-pulleys clearly shown in both figures. The spindle-pulley is a two-step cone, and another two-step cone is mounted on the counter-shaft for each spindle. Six spindle speeds can be obtained, since either of the steps of the countershaft cone can be used with either of the steps of the spindle-cone, and the counter-shaft itself is large enough to be used as a driving-pulley for the two lowest speeds. The counter-shaft cone is arranged to adjust itself automatically along the shaft, so as to enable the belt to track properly on its two steps, and the idler-pulley is stepped so that when the belt is changed from one step to the other the slack is taken up and the belt is brought into line with either step of the spindle-cone. The idler-pulleys can be adjusted in a horizontal direction to take up the slack of the belts by means of screws operated by small hand-wheels visible in both illustrations. The counter-shaft runs on ball-bearings, and the loose pulley, which is also provided with ball-bearings, is designed so as to relieve the tension on the belt when the machine is not in use. The whole counter-shaft, with its cone-pulleys, is reversible, so that the driving-pulleys can be placed on either side of the machine. The belt-shifting fork can be operated by ball-handles, placed at the back of the machine on both sides.

Three types of spindles are used with these machines. Those shown in Fig. 1 are plain spindles, with hand-feed, operated by rack and pinion by means of a double-ended hand-lever, which is held in a spring socket, so that it can be pulled out either way to a convenient length for the work being done. The spindles are adjustable in a vertical direction and can be clamped in any position; they are balanced by springs, and adjustable stops are provided to regulate the depths of the holes drilled. The two other types of spindles are represented on the machine illustrated in Fig. 2, in which the left-hand spindle is plain and the other geared; both are, however, fitted with the firm's patent self-engaging automatic feed. With this feed the operator has only to pull down the feed-lever until the drill comes into contact with the work, when the automatic feed comes into action and continues to feed the drill into the work. When the required depth is reached, the feed is disengaged by means of a stop, and the drill is automatically withdrawn from the hole. It is thus possible for the operator to keep all the spindles of a multiple drill engaged simultaneously by setting up work under one spindle while others are drilling; a large output can thus be maintained without fatiguing the operator. The drill can be stopped and withdrawn at any point by moving the hand-lever upwards, if for any reason it should be necessary to do so. Three different rates of feed are provided, the changes being effected by turning a knob on the spindle-head, Fig. 2, near the end of the feed-lever. The heads in this machine are balanced by weights suspended inside the columns, and attached to the heads by means of chains passing over sheaves at the tops of the slides.

Drills with plain spindles may be used for drilling holes up to 1 in. in diameter, and for tapping up to $\frac{5}{8}$-in. holes in cast iron, or $\frac{3}{4}$-in. holes in mild steel. Geared-spindle drills are suitable for drilling up to $1\frac{1}{4}$ in. in diameter, and for tapping blind holes up to $\frac{3}{4}$ in. in diameter in either cast iron or mild steel; through holes up to 1 in. in diameter can be tapped with these machines. They can be supplied with either one, two, three, or four spindles, which are usually spaced 9 in. apart; but if additional width is required between the spindles, two or three heads can be fitted respectively on the pedestal and table usually provided with three or four heads. Ball-bearings are employed throughout for all running parts, and the firm claim that their use enables a quicker feed to be employed, and also renders it possible to drill larger holes than could otherwise be done on sensitive drills. The ball-bearings are put together in dust-proof housings, with a supply of grease that lasts indefinitely; they are interchangeable and of standard trade sizes. We understand that in a test carried out in Messrs. Herbert's works, using twist-drills of high-speed steel on one of these machines a hole $\frac{7}{8}$ in. in diameter was drilled in cast iron, of 238 Brinell hardness number, at the rate of 15 in. per minute, and that a $\frac{1}{4}$ in. hole in the same material was drilled at the rate of 50 in. per minute. The speed of the $\frac{7}{8}$-in. drill was 600 revolutions per minute, and that of the $\frac{1}{4}$ in. drill 2050 revolutions per minute.

SOME QUESTIONS IN CONNECTION WITH THE WORK OF THE LOAD-LINE COMMITTEE.*

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§ 1. This paper has been prepared with the object of placing before the Institution a brief record of some features of the work done by the recent Load-Line Committee, more particularly the formulation of a suitable standard of structural strength which might be adopted

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internationally for the necessary tests which it is desirable to lay down in order that the freeboard assigned shall not be so small as to bring undue strains upon the structure of a vessel. In accordance with the commonly accepted practice in such matters, the procedure proposed provides distinct treatment of the two principal straining actions to which the structure of a vessel is subjected, and the following account deals separately with the questions of longitudinal strength and the strength of the transverse hold framing.

LONGITUDINAL STRENGTH.

§ 2. The method of procedure to determine a suitable standard of longitudinal strength, which was first considered, was to follow the lines of the ordinary calculations adopted for the purpose of comparing the strengths of somewhat similar vessels. It will be remembered that the procedure adopted in such calculations is to determine the longitudinal bending moment on the structure for a vessel poised upon a wave under certain conditions of loading, the height of the wave being taken as a fraction of the wave-length, which is taken to be the length of the vessel. It is known that the height of waves which are commonly met with are not strictly proportional to the length, and that with long waves the height should be taken at a less ratio than for short waves. Consequently, it will be seen that the assumptions made in estimating the longitudinal bending moment are such as to give rise to a variety of differences of opinion.

Moreover, when this calculation is complete, it is customary to determine a hypothetical stress by the use of the bending-moment formula, $\frac{p}{y} = \frac{M}{I}$, which formula in itself is only true within very narrow limits. Further, it is found that the hypothetical stress so determined varies, according to common practice, with the length, being taken to be as much as 10 tons per in. square for very long ships. It was therefore seen, after very brief investigation, that the work involved in laying down a stress factor in terms of dimensions would be very great, and, further, would be open to a variety of objections, which would depend to a great extent on individual opinion and experience.

§ 3. A method was then sought which, while expressing the same factors, would yet take account of them in a form which was free from some of the defects detailed above. It will be seen that the bending equation may be written in the form: $\frac{I}{y} = \frac{M}{p}$, in which the left-hand side of the equation is a perfectly definable and calculable quantity when the midship section of the vessel is known, while the right-hand side contains the ratio of the two hypothetical quantities, which are not easily defined. Moreover, the ratio $\frac{I}{y}$, which is purely geometrical, was obviously more suitable for expression in terms of the principal geometrical dimensions of a vessel.

§ 4. The rules of the registration societies provide for a determination of scantlings in terms of the principal dimensions. These rules have been developed from experience with actual vessels on sea service, and consequently may be assumed to take account of the greater proportion of variations in loading, bending moment, and stress values which have been met with over a period of years. The object of such an investigation as is here considered being to obtain a general average of experience with ship structures at sea, it at once followed that the basis of any analysis should be the rules of these societies.

§ 5. The method of procedure adopted was to analyse the rules of the principal registration societies in terms of $\frac{I}{y}$ and the principal dimensions of the vessel, with a view to obtaining a standard of longitudinal strength which would rationally express the minimum requirements found necessary from successful sea experience.

§ 6. It at once became apparent that a number of factors would have to be taken into account. The points requiring investigation may be summarised, and will be considered in the following order :—

(*a*) The longitudinal modulus of resistance, $\frac{I}{y}$.

(*b*) The distribution of the material, in order to ensure sufficient material in the web of the girder, which involves a limiting thickness of side plating.

(*c*) The frame spacing, which requires limitation in order that the web of the girder may not fail from secondary bending.

(*d*) The stiffness of structure, which may impose a limitation, since, if the proportion of length to depth be excessive, failure may arise through deflection.

(*a*) THE LONGITUDINAL MODULUS OF RESISTANCE $\frac{I}{y}$.

§ 7. For the basic calculations a series of vessels were considered with lengths of every 100 ft. up to and including 600 ft. Four ratios of $\frac{\text{length}}{\text{depth}}$ were used for each length—namely, 10, 11, 12, and 13.5. A standard beam $B = \frac{L}{10} + 10$ was taken. The depth used for the $\frac{\text{length}}{\text{depth}}$ ratio was the depth to the strength deck, the strength deck being defined as the uppermost deck which is incorporated into and forms an integral part of the longitudinal girder within the half-length amidships.

Two types of vessels were considered—namely, the flush-deck full-scantling vessel, which fulfilled the highest requirements of the registration societies ; and the complete superstructure vessel, which fulfilled the requirements of the registration societies for the awning-deck or shelter-deck type.

§ 8. It was decided for the sake of convenience that the modulus of section $\frac{I}{y}$ should be calculated for a section of the ship through the cargo hold clear of the hatch. The standard moment of inertia (I) was calculated without deductions for rivet-holes or any deck openings. Below the strength deck all longitudinally continuous members were included, with the exception of such parts of underdeck girders as are entirely required for pillaring purposes. Above the strength deck the only members included were the gunwale bar and the extension of the sheer strake above the strength deck. The distance (y) was measured from the neutral axis to the under side of the strength-deck stringer at side. In order that the minimum requirements of the registration societies should be obtained, the number of decks was kept as low as the rules permitted. The 'tween-deck height below the freeboard deck was taken as 8 ft. in all cases; but the height in feet of the superstructure was taken the same as in the freeboard rules—viz., $0.018\,L + 1.2$ ft., where L is the length of the vessel in feet, with a minimum height of 3 ft. and a maximum height of 7.5 ft. It will be observed that the details of the calculation have been reduced to the fewest possible terms, since simplicity of calculation and definition was eminently desirable. On the other hand, no loss of accuracy arises, since the principal quantities concerned are included, and since the standard is comparative only.

§ 9. The values of the modulus of resistance $\frac{I}{y}$ were calculated for the whole series of vessels, and the results for each $\frac{L}{D}$ value for the full-scantling and the complete superstructure vessels were plotted on a length base. The values for each society were faired by parabolic curves, and a fair minimum envelope drawn for each $\frac{L}{D}$ value. These envelope curves consisted of eight separate curves—namely, one for each type for each value of $\frac{L}{D}$. From these curves a series of standard $\frac{I}{y}$ values could have been tabulated for various lengths and for each $\frac{L}{D}$ value. An attempt was made to reduce these curves to a convenient general form of the order :—

$$\frac{I}{y} = c\,L^n + c'\,L^m,$$

but no consistent results were obtainable.

§ 10. It was then necessary to determine, if possible, some common basis on which the results might be correlated and faired. For a series of vessels of similar type and of given principal dimensions and proportions, it may be reasonably assumed that the bending moment M varies as displacement × length ; that is :—

$$M \propto \Delta\,L \propto L\,B\,d \times L,$$

where d is the draught. It was found, as already indicated, that the stress p is a function of the length L, and to the first order of approximation could be expressed in the form $p = a\,L + b$; *i.e.*, $p \propto L$. Consequently :—

$$\frac{I}{y} = \frac{M}{p} \propto \frac{L\,B\,d\,.\,L}{L} \propto L\,B\,d\,;$$

that is, $\frac{I}{y}$ varies as draught, for constant length and breadth. Now, a full-scantling and a complete superstructure vessel of the same principal dimensions vary so far as their scantlings are concerned by reason of the factor draught ; the strength should, therefore, also vary as the draught d. It thus appeared that draught as a main factor would be most likely to lead to a possible combination of the several results.

§ 11. The calculated values of the modulus of resistance were then plotted in various ways, but the best results were obtained on a base of draught for constant length. It was found that the best minimum fairing curve in each case was a radial straight line through the origin. This line faired the spots for both the full-scantling and the complete superstructure vessels. An examination of such curves justified the assumption that "$\frac{I}{y}$ varies directly with the draught, or $\frac{I}{y\,d}$ is constant for constant length and breadth." The cross fairing was performed by plotting $\frac{I}{y\,B\,d}$ on a length base. In the above calculations the draught taken for the complete superstructure vessel was that given by the freeboard tables for the awning-deck class. In the case of the full-scantling vessel, since the addition of a poop and forecastle and the provision of the maximum sheer permitted by the freeboard rules does not increase the structural scantlings, although permitting a reduction of the freeboard, the Table A freeboard, less 12½ per cent., was used to calculate the draught for the full-scantling vessel.

§ 12. The foregoing analysis assumed that the beam was equal to $\frac{L}{10} + 10$, and an investigation was then made to determine the effect of variation of beam from this standard.

Using the formula already quoted—namely :—

$$\frac{I}{y} \propto L\,B\,d,$$

and knowing that for a vessel of constant length and depth the draught is fixed, and is independent of the beam, it was to be anticipated that the $\frac{I}{y}$ should in practice vary directly as the beam. To verify this conjecture the value of the modulus of resistance was also calculated both for the full-scantling and the complete superstructure vessel for constant length and depth, but for beams equal to :—

$$\frac{L}{10} + 5,\ \frac{L}{10} + 15,\ \text{and}\ \frac{L}{10} + 20.$$

The results were plotted on a breadth base, and they showed that within these limits the modulus of resistance $\left(\frac{I}{y}\right)$ varied directly as the beam. The assumption was therefore justified that "$\frac{I}{y}$ varies directly with the beam, or $\frac{I}{y\,B}$ is constant for constant length and draught." These two verifications justified the basis of the conclusions with regard to longitudinal strength ; they may be summarised as follows :—

(1) $\frac{I}{y\,d}$ = constant, if L and B are constant.

(2) $\frac{I}{y\,B}$ = constant, if L and d are constant.

It at once follows that :—

$\frac{I}{y\,B\,d}$ = constant, if L is constant.

§ 13. The rules of the registration societies fix the detailed scantlings on the principal dimensions of the vessel, and, consequently, the value of the modulus of resistance calculated for small increments of length results in practice in a series of steps. To allow for such graduation it was found necessary to reduce the average minimum values already obtained by 5 per cent.

§ 14. In a comparative calculation of this nature the adoption of a standard modulus of resistance necessarily implies a definition of the material of which the structure is composed. Consequently it was necessary to fix a standard, which was defined as follows :—The standard of strength assumes that the structure is built of mild steel, manufactured by the open-hearth process (acid or basic), which has a tensile strength of 27 to 32 tons per sq. in., and an elongation of 20 per cent. on a length of 8 in. measured on a British standard test-piece.

§ 15. The calculations were carried out for a particular block coefficient. It may be observed that in a vessel of constant dimensions and draught, the statical bending moment may reasonably vary with distribution of form, and from this point of view it may be considered that the standard of strength should take some account of variation of fineness which is most commonly measured by block coefficient. On the other hand, a fine form is only adopted for economic reasons when it is desired to obtain speed above the ordinary, and such vessels will be subjected to increased dynamical strains the amount of which are not easily measureable. Consequently it was considered preferable, in the light of present knowledge, to adhere to the practice uniformly adopted for cargo-carrying vessels of ordinary type, and to make no allowance for variation in block coefficient.

§ 16. The method of procedure may with advantage be summarised as follows :—

1. The calculated values of $\frac{I}{y}$ for the full-scantling and the complete superstructure vessels for the four values of $\frac{L}{D}$ were plotted on a draught base for constant length.

2. Rational minimum curves were obtained by drawing a radial straight line through the origin in each case.

3. A second radial line was then drawn 5 per cent. below the previous one, which represents the standard $\frac{I}{y\,d}$ for each length.

4. The values of $\frac{I}{y\,d}$ were then plotted on a length base, and, after cross-fairing, a curve was drawn through the spots.

5. The values of $\frac{I}{y\,d}$ were measured at various points and divided by the factor :—

$$\frac{L}{10} + 10$$

to determine the value of $\frac{I}{y\,B\,d}$.

6. These values were then plotted on a large scale on a length base, and the ordinates of the curve tabulated for every 20 ft.

7. The values of f for the formula :—

$$\frac{I}{y} = f\,B\,d$$

were obtained and the standard of longitudinal strength determined.

§ 17. In the way of hatch openings the minimum values of the modulus of resistance were obtained for the same series of vessels. These were plotted and a faired curve of $\frac{I}{y\,d}$ on length obtained, from which it was determined that an allowance of 10 per cent. reduction for the modulus of resistance of a section through a hatch was sufficient where at least one steel deck was fitted.

(*b*) THICKNESS OF SIDE PLATING.

§ 18. It was first necessary to determine some suitable basis on which a sensible comparison was likely to be obtained. The web of the girder, which in a vessel is the side plating, has to stand the shearing force. The relation between the quantities concerned is given by the formula :—

$$t = \frac{F\,m}{I\,q},$$

where q = shear stress at neutral axis; m = half the total moment of the longitudinal members above the neutral axis about that axis; t = thickness of side-plating; I = moment of inertia of the section about the neutral axis; and F = maximum shearing force at the section. The maximum stress due to longitudinal bending varies as the length, and it is therefore permissible to assume that the maximum shear stress q also varies as the length. It may also be assumed that:—

$$F \propto \text{displacement} \propto L\,B\,d,$$

whence:—

$$t \propto B\,d\,\frac{m}{I}.$$

Now $\frac{m}{I}\frac{D}{}$ is constant for similar geometrical sections, and it was found that this relation applied to actual vessels. Consequently:—

$$t \propto B\,\frac{d}{D}.$$

For a particular type of ship $\frac{d}{D}$ is constant, and the beam can be taken as a function of the length, or:—

$$B = a\,L + b,$$

whence:—

$$t \propto a\,L + b.$$

This reasoning indicated that the thickness of the side plating might be expected to vary directly as the length, and this assumption was justified by an investigation of the minimum requirements of the registration societies.

The formula actually arrived at was:—

$$t = 0.105\,L + 17,$$

where L is the length of the vessel in feet and t the thickness of the side plating in hundredths of an inch. This formula also includes an allowance for the graduation of the various rules. The variation of thickness of side plating with variation of beam was found to be within the limits of error of the formula, and was therefore neglected.

(c) Frame Spacing.

§ 19. To prevent failure from secondary bending it is necessary that the plating shall be properly supported, and that some relation should exist between the minimum thickness of side plating and the frame spacing. The rules of the various societies differ slightly as regards the thickness of side plating and frame spacing required for a given vessel. It was therefore necessary to reduce the various requirements to a common comparable basis. The minimum thickness of side plating had already been determined, and it was decided to use this as the fixed factor and to reduce the various requirements to this base. From theoretical grounds it appeared probable that the minimum thickness t should vary directly with the frame spacing s. This did not agree with actual practice, and it was found that the empirical formula:—

$$\frac{t_1}{t_2} = \sqrt{\frac{s_1}{s_2}}$$

gave satisfactory results when tested against practical cases where the difference between s_1 and s_2 was not relatively great.

By means of the formula quoted above, the frame spacing required for each society for the standard thickness of side plating was obtained, and the results plotted on a length base. It was found that the maximum spacing permitted would be faired by a straight line:—

$$s = 0.025\,L + 17,$$

where s is the frame spacing in inches and L the length in feet. This law did not apply below 160 ft., and consequently the minimum frame spacing was fixed at 21 in.

(d) Stiffness of the Girder.

§ 20. This quantity, other things being the same, is dependent on the ratio of length to depth, and it was decided that this factor could be taken account of by limiting the application of the standard of strength to the length to depth ratios for which the calculations were made.

Strength of Hold Frames.

§ 21. The object of the investigation was to obtain a simple and effective basis of comparison for the strength of hold frames which would be generally applicable. For this purpose the requirements of the principal registration societies, as given in their printed rules, were taken as representative of present-day practice. It was desirable to cover the widest practicable ranges, both of dimensions and type, and at the same time to express the results in terms of simple factors, rather than to strive after refinement of accuracy.

§ 22. The principal variables first dealt with were:—Moulded depth (D), moulded depth to lowest tier of beams (h), moulded breadth (B), frame spacing (s), side plating, modulus of section of frame girder $\left(\frac{I}{y}\right)$. It will be observed that the original intention was to correlate principal dimensions and strength of hold frames. The factor of draught was left until a later date, it being considered that for a first analysis there was a reasonably and sufficiently constant ratio of draught to moulded depth.

§ 23. As regards these principal variables, it was possible to reduce the number, which was inconveniently great for analytical purposes, either by entire elimination or by relation to one of the other variables.

Variation of Beam.—The forces straining the frame girder are those due to the water pressure and those due to the deck cargo load above the frame. The water-pressure effect is independent of the beam, but the end load and the bending moment due to deck cargo vary with the breadth. The deck cargo load is divided between the frame and the nearest row of pillars, and in a vessel with two rows of pillars only about one-sixth of the load could be considered as acting on the frame. Consequently the effect of variation of beam for a given number of rows of pillars was found to involve very little variation of the load on the ship's frame. It may also be noted that the maximum variation of scantlings for alteration of beam only were well within the limits of accuracy required; consequently, subject to the proviso that the span from the frame to the first row of pillars should not exceed 20 ft., the effect of variation of beam is neglected.

Side Plating.—Strictly speaking, the transverse modulus of resistance of the frame-girder is the value of $\frac{I}{y}$ of a section composed of the frame and that proportion of the shell-plating which acts with the frame. It was found extremely difficult to make such a calculation for the large variation of range of dimensions considered desirable, and no attempt was made to standardise the modulus of resistance of the frame-girder proper. Nor was this necessary, since the investigation was comparative only, and was not concerned with an estimate of actual stresses. The minimum thickness of the plating and the frame spacing are fixed (see longitudinal strength); therefore it is only necessary to fix the frame to complete the girder. The number of variables was thus reduced by the elimination of "side plating."

§ 24. It was now necessary to tabulate the hold-frame requirements of the various registration societies, and for this purpose the value of $\frac{L}{D}$ was taken equal to 12, and $B = \frac{L}{10} + 10$. By interpolation and extrapolation a table was drawn up showing the frames required for vessels having a moulded depth to strength deck varying from 15 ft. to 60 ft., and a depth of hold varying from 8 ft. to 27 ft. This series of hold frames formed the basis of all the subsequent calculations, which were carried out with the view of obtaining a method of analysis giving acceptable limits of error.

§ 25. The deep-frame system of framing was used, and the aim of the investigation was to establish a basis of strength which should apply to the standard frame, which was defined as follows:—"The standard transverse frame is composed of a frame angle and a reverse angle each of the same size and thickness." It was impossible with the wide range of D and h values taken to adhere to the same type of framing in every case, and where the societies' rules gave only a frame and reverse, a bulb angle, a channel, or some combination such as a channel and reverse, the equivalent deep frame was obtained.

§ 26. At the higher limits the majority of the tabulated values were on the web-frame system, and attempts were made to find a method by which an equivalent deep frame might be obtained. The most promising of these was based on the fact that for a deep frame the $\frac{I}{y}$ of the frame itself, neglecting shell-plating, was measured by $\delta^2 t$ where, δ = depth of frame and t = thickness. It was found in a number of cases where both web frames and deep frames were obtainable for the same vessel, that the mean value of $\delta^2 t$ for the web frame and its group of intermediate frames was approximately proportional to the $\delta^2 t$ for the deep frame required for the same vessel. This did not prove sufficiently general, but it was seen that an ample range of values was obtainable even if the web-frames were neglected.

§ 27. The plotting of the above $\delta^2 t$ results showed that generally the values of $\delta^2 t$ for the deep-frame system on a base of h gave more consistent results than did $\frac{I}{y}$ on the same base; and this led to an attempt to fix the framing standard by obtaining some simple method of expressing either $\delta^2 t$ or δ and t separately in terms of the main variables. The values given by each society for different types of vessel were examined separately, and good approximations were obtained so long as the type and number of decks were fixed. For example, it was found in one case that the minimum thickness of the deep frame for all two-deck vessels up to D = 36, having an 8-ft. 'tween deck height, could be expressed in the form:—

$$t = \text{const.}\ (B + D) + \text{const.},$$

and the corresponding depth of frame in the form:—

$$\delta = \text{const.}\ D\,(D - 8) + \text{const.}$$

This idea was abandoned because of the impossibility of reconciling all the formulæ obtained for different numbers of decks.

§ 28. The next method tried was to plot the $\frac{I}{y}$ of the deep frame on a base of moulded depth to lowest tier of beams (h) for varying values of the moulded depth D. As mentioned above, the calculated values of $\frac{I}{y}$ were not very consistent, and, in order to obtain a better comparison between the requirements of the various societies, it was decided to use the $\frac{I}{y}$ of the frame girder per unit frame spacing, or $\frac{I}{y\,s}$ as the variable to be plotted. These results again proved unfair, and it was found necessary to approach the problem along slightly different lines.

§ 29. The loading on the frame may be divided into two parts—viz. (1) water-pressure load, and (2) cargo load carried above the deck. The bending moment on the frame due to the water pressure varies with the load and the span. The load is a function of the head of water, which is approximately measured by the draught (d) of the vessel, and of the frame spacing (s). The effective span of the frame is more or less indeterminate, and as a first approximation it was taken as proportional to the moulded depth to lowest tier of beams h. The bending moment due to water load may be represented by a formula of the nature:—

$$M \propto s\,.\,d\,.\,f(h),$$

where f (h) is some function of the moulded depth to lowest tier of beams. The cargo load exerts a bending moment and a compressive force on the frame. The bending moment can be divided into two parts—namely, that due to the end compressive load acting on a deflected strut, and that due to the cargo load direct. Both these moments are comparatively small, and, moreover, since they are of the opposite sign to the bending moment due to water pressure, they may be ignored in obtaining a first approximation to a characteristic formula. The compressive load on the end of the frame depends on the height of the superimposed cargo space, the frame spacing, and the span between the frame and the first row of pillars. It has already been shown that the effect of span is small so long as its value is less than, say, 20 ft. Consequently the end load may be written in the form:—

$$W \propto s\,\phi\,(K),$$

where K is the depth of superimposed cargo space.

§ 30. The total stress (p) in the frame will be of the form:—

$$p \propto \frac{\frac{M}{I}}{y} + \frac{W}{A}$$

$$\propto \frac{\frac{s\,.\,d}{I}}{y} f(h) + \frac{s}{A} f(K),$$

where A is the cross-sectional area of the frame. For a standard type of framing there appeared to be a reasonably constant relation between $\frac{I}{y}$ and A. Consequently the number of variables may be reduced, and the formula simplified for purposes of analysis, by writing:—

$$p \propto \frac{s\,d}{\frac{I}{y}} [f(h) + \phi(K)]$$

Further, since the working stress may be assumed constant for a given material, the relation may be written:—

$$\frac{I}{y\,.\,s\,.\,d} = f(h) + \phi(K)$$

Such arguments indicated that the analysis of the quantity $\frac{I}{y\,s\,d}$ in respect of the two variables, span of frame and height of cargo space, would be most likely to yield satisfactory results.

§ 31. The value of the draught factor in the formula was at once apparent, for it was now possible to treat the flush-deck full-scantling vessel and the complete superstructure vessel on the same basis. Two vessels which have the same principal dimensions may be of either type, and the main difference to be taken account of in a comparison is that of draught. Now draught is a measure of the load on the frame, and, therefore, of the stress in the frame. Hence, if the modulus of resistance of the frame is taken, not only per unit frame spacing, but also per unit of draught, then the two types mentioned can be directly compared and combined into a common formula.

§ 32. The introduction of the factor draught brought a new variable into the argument, and it was considered advisable to inquire what other changes would be consequent on this modification. Thus far, the calculation had only been made for a particular $\frac{L}{D}$ ratio of 12, with the knowledge that at some later stage other values of this ratio would have to be taken into account. Owing to the construction of the Freeboard Tables, it will be found that for constant depth, as the $\frac{L}{D}$ ratio increases, the draught decreases. On the other hand, in dealing with the question of longitudinal strength, it was found that the frame spacing should increase directly with the length. Consequently it would appear that the quantity $s\,d$, which is a measure of the load on the frame, might be approximately independent of length-depth ratio. It was found on investigation that within the limits of the freeboard tables this product was sufficiently constant to make it possible to ignore the effect of the length-depth ratio in considering the strength of transverse framing.

§ 33. As a first approximation, the moulded depth D was substituted for the slightly more indefinite factor K, and the values of $\frac{I}{y\,s\,d}$ were plotted on a base of moulded depth (D) for constant values of the moulded depth to lowest tier of beams h. The best envelope of minimum values was obtained by a straight line in each case. Since the modulus of resistance of a girder varies as the square of the span, the cross-fairing for different values of the moulded depth was performed on a base of h^2. The formula for the strength of the hold frame was now in the form:—

$$\frac{I}{y\,s\,d} = f + f_1,$$

where f and f_1 were constants depending on h and D respectively, which constants could be obtained from the fairing curves.

§ 34. So far the special case of the single-deck ships had not been considered; but it was found that they could very well be included, and that their variation from

the faired minimum was no greater than in the case of vessels with more than one deck. The values plotted thus included every possible case for the societies, and it was decided, in order to limit the amount of variation to be considered in determining the fairing lines, to eliminate, so far as possible, all unnecessary values. For this purpose only those spots which represented the absolute minimum requirements for each society were included. A further step in the same direction was made by carrying out the plotting process in two stages. The first plotting faired the values of $\frac{I}{y\,s}$ for each society on a basis of h_2 for constant values of D, and the second plotting was $\frac{I}{y\,s\,d}$ (obtained from the first fairing curves) on a base of D for constant h value.

§ 35. The next modification introduced was made to obtain a more accurate measure of the span of the frame than was given by the moulded depth to lowest tier of beams. The latter factor would have been the simplest basis, but it introduced too large an error, and had to be abandoned for something more accurate, but not so readily determined. The new span (H) is defined as follows:—"H is the vertical distance in feet from the top of the lowest tier of beams at side to a point which is midway between the top of the inner bottom at side and the top of the heel bracket in vessels fitted with double bottoms. Where there is no double bottom H is to be measured to a point which is midway between the top of the floor at centre and the top of the floor at side." Even with this modification, it was found that there were still large limits of error, and it was necessary to introduce some further refinement in the method of analysis. Returning to the formula :—

$$\frac{I}{y\,s\,d} = f(h) + \phi(K),$$

which should now be :—

$$= f(H) + \phi(K),$$

the previous analysis showed that the first term on the right-hand side of the equation was very much more important than the second term, which depended on moulded depth (D). However, since this term D affected both H and K to an unknown extent, it was thought that a further differentiation might take place by dealing with the K factor direct.

The factor K was defined as follows:—"K is the vertical distance in feet from the top of the lowest tier of beams at side to a point which is 7 ft. 6 in. above the freeboard deck at side, or, if there is a superstructure, to a point 12 ft. 6 in. above the freeboard deck at side." On this new base the values of $\frac{I}{y\,s\,d}$ for different H values were faired by a series of parallel curves and cross-faired on a base of H^2 for different values of K. It is obvious that the prime factor which is dependent on H is given directly by the curve for K = 0.

§ 36. To reduce further the limits of error of the formula, the draught (d) in the expression was subsequently modified to $(d - t)$, where t was defined as follows:—"t is the vertical distance in feet from the top of the keel to a point which is midway between the top of the inner bottom at side and the top of the keel bracket. Where there is no double bottom t is to be measured to a point which is midway between the top of the floor at centre and the top of the floor at side." It may be observed, since draught was considered to be a measure of the main load on the frame, that $(d-t)$ is a more accurate measure than d.

§ 37. The formula now becomes :—

$$\frac{I}{y} = s(d-t)\{f_1 + f_2\},$$

where f is a constant depending on the value of H, and f_2 a constant depending on K.

§ 38. To summarise the method of procedure finally adopted :—

(*a*) The values of $\frac{I}{y\,s}$ were calculated from the tables of framing for each society, and the minimum values were tabulated.

(*b*) These values were plotted on a base of H^2 for different values of the moulded depth D.

(*c*) The values of $\frac{I}{y\,s}$ were tabulated for a series of H and D values. The equivalent values of $(d-t)$ and K were determined, and hence values of $\frac{I}{y\,s\,(d-t)}$ were obtained.

(*d*) Values of $\frac{I}{y\,s\,(d-t)}$ were then plotted on a base of K for constant values of H, and curves were drawn to represent the rational minimum fair values. For different values of H these curves were parallel.

(*e*) Values of $\frac{I}{y\,s\,(d-t)}$ were cross-faired by plotting on a base of H^2 for constant values of K.

(*f*) The curve for K = 0 gave the values of f_1, which were tabulated for different values of H.

(*g*) A table was made out for the constant f_2 depending on K.

(*h*) The standard strength for transverse framing was finally given by the formula : —

$$\frac{I}{y} = s(d-t)\{f_1 + f_2\}.$$

§ 39. It will readily be understood that the work, so briefly summarised here, could only have been rendered possible by the united efforts of all members of the Committee and by the unstinted help rendered by the technical assistants who carried out the elaborate and involved work necessary for the various analyses that have been mentioned. In this respect particular reference must be made to the services of Mr. W. M. Balfour, B.Sc. (now Lieutenant, R.G.A.), who was my assistant at the University of Liverpool, and who acted as the head of the technical staff employed on this work.

APPENDIX.

For purposes of record, the following abstract of the standard of strength proposed by the Load-Line Committee is appended :—

STANDARD STRENGTH.

Standard strength as expressed in Clauses (1) to (4) is applicable to cargo-carrying vessels of ordinary type.

(1) DEFINITIONS.

(i.) *Material.*—The standard of strength assumes that the structure is built of mild steel, manufactured by the open-hearth process (acid or basic), which has a tensile strength of 27 to 32 tons per sq. in., and an elongation of 20 per cent. on a length of 8 in. measured on a British standard test-piece.

(ii.) *Dimensions : Length.*—The length to be used is the length on the summer load water-line from the foreside of the stem to the afterside of the rudder-post. Where there is no rudder-post, the length is to be measured from the foreside of the stem to the centre of the rudder stock.

Breadth.—The breadth to be used is the maximum breadth to the outside of the frame amidships.

Depth to Strength Deck, hereinafter called "strength depth," is to be measured from the top of the keel to the under side of the strength-deck stringer at the side of the vessel amidships.

Draught is to be measured in feet from the top of the keel to the centre of the disc.

(iii.) *Strength Deck.*—The strength deck is the uppermost deck which is incorporated into and forms an integral part of the longitudinal girder within the half-length amidships.

(2) STANDARD OF LONGITUDINAL STRENGTH FOR NEW VESSELS.

(i.) *Longitudinal Modulus of Resistance.*—The longitudinal modulus of resistance is the moment of inertia (I) of the midship section about the neutral axis divided by the distance (y) measured from the neutral axis to the underside of the strength-deck stringer at side. The standard moment of inertia of the midship section is calculated without deductions for deck openings or rivet-holes. The areas are to be measured in square inches and the distances in feet. Below the strength deck, all longitudinally continuous members are to be included with the exception of such parts of under-deck girders as are entirely required for pillaring purposes. Above the strength deck, the only members included are the gunwale angle bar and the extension of the sheer strake above the strength deck.

(ii.) *Standard of Longitudinal Strength.*—The standard of longitudinal strength is measured by the modulus of resistance $\frac{I}{y}$ as defined above and is given by :—

$$\frac{I}{y} = f\,d\,B,$$

where I is measured in square inches—square feet ; y is measured in feet; B is the breadth in feet; d is the draught in feet from the top of the keel to the centre of the disc ; and f is a factor on a basis of length and is given by the following table :—

Longitudinal Strength Factor f.

Length in Feet.	*f*.	Length in Feet.	*f*.
100	2.00	360	10.50
120	2.25	380	11.50
140	2.60	400	12.50
160	3.00	420	13.50
180	3.50	440	14.60
200	4.00	460	15.70
220	4.60	480	16.80
240	5.30	500	18.00
260	6.10	520	19.20
280	6.90	540	20.40
300	7.70	560	21.70
320	8.60	580	23.10
340	9.50	600	24.60

For intermediate lengths the value of f is determined by linear interpolation.

This formula applies to vessels having a length which does not exceed 600 ft., a breadth which is between

$$\frac{L}{10} + 5 \text{ and } \frac{L}{10} + 20,$$

both inclusive (where L is the length in feet), and a ratio of length to depth to strength deck, hereinafter called the "strength length-depth ratio," which is between 10 and 13.5, both inclusive. The modulus of resistance in the way of the deck openings must not be less than 90 per cent. of the standard value.

(iii.) *Standard Frame Spacing and Thickness of Side Plating.*—The standard minimum thickness of side plating in hundredths of an inch is (0.105 L + 17) and the standard maximum frame spacing in inches for side plating of this thickness is 21 in. in vessels not exceeding 160 ft. in length, and in vessels of greater length is (0.025 L + 17), where L is the length of the vessel in feet.

(3) STANDARD OF TRANSVERSE STRENGTH FOR NEW VESSELS.

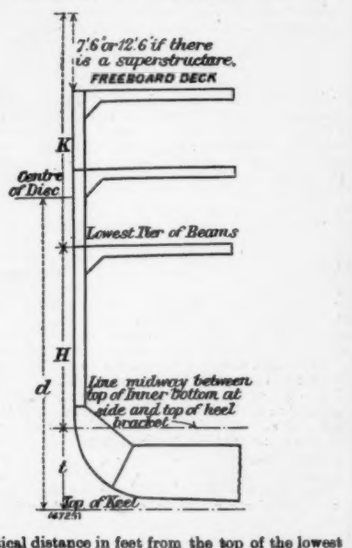
(i.) *The Standard Transverse Frame.*—The standard transverse frame is composed of a frame angle and a reverse angle each of the same size and thickness.

(ii.) *The Transverse Modulus of Resistance.*—The transverse modulus of resistance is the moment of inertia (I) of the standard frame section about the neutral axis divided by the distance (y) measured from the neutral axis to the extremity of the frame section without deduction for rivet and bolt-holes. It is applied to the midship frame below the lowest tier of beams, and it is measured in inch units.

(iii.) *Standard of Transverse Strength.*—The standard of transverse strength is measured by the transverse modulus of resistance $\frac{I}{y}$ as defined in Clause (ii.), and is given by :—

$$\frac{I}{y} = \frac{s\,(d-t)\,(f_1 + f_2)}{1000},$$

where I is measured in square inches—inch ; y is measured in inches ; s is the frame spacing in inches ; d is the draught in feet from the top of the keel to the centre of the disc ; t is the vertical distance in feet from the top of the keel to a point which is midway between the top of the inner bottom at side and the top of the heel-bracket. Where there is no double bottom t is to be measured to a point which is midway between the top of the floor at centre and the top of the floor at side (see Fig. 1). f_1 is a coefficient depending on H, which



is the vertical distance in feet from the top of the lowest tier of beams at side to a point which is midway between the top of the inner bottom at side and the top of the heel-bracket in vessels fitted with double bottoms. Where there is no double bottom H is to be measured to a point which is midway between the top of the floor at centre and the top of the floor at side (see Fig. 1). f_2 is a coefficient depending on K, which is the vertical distance in feet from the top of the lowest tier of beams at side to a point which is 7 ft. 6 in. above the freeboard deck at side, or, if there is a superstructure, to a point 12 ft. 6 in. above the freeboard deck at side (see Fig. 1). The values of f_1 and f_2 are given in the following tables :—

H in Feet ..	0	8	10	12	14	16	18	20	22	24	26
f_1	9	11	12.5	15	19	24	29.5	36	43	51	59

K in Feet	0	5	10	15	20	25	30	35	40
f_2	0	0.5	1.0	2.0	3.0	4.5	6.5	9.0	12.0

Intermediate values are to be determined by interpolation. This formula applies to vessels having a depth which is between 15 ft. and 60 ft., both inclusive, a breadth which is between :—

$$\frac{L}{10} + 5 \text{ and } \frac{L}{10} + 20,$$

both inclusive (where L is the length in feet), and a strength length-depth ratio which is between 10 and 13.5, both inclusive; provided that the horizontal distance from the outside of the frame to the centre of the first row of pillars does not exceed 20 ft.

(iv.) *Transverse Stiffness.*—The assigning authority is to be satisfied that the distribution of material is such that the transverse framing has sufficient stiffness.

(4) EXTENT OF MIDSHIP SCANTLINGS.

The midship scantlings are to extend at least throughout half the length amidships, or an equivalent construction is to be provided.

CANADIAN RAILWAYS.—There are now 35,583 miles of railway in operation in Canada. In the course of last year the Grand Trunk system handled 1,376,189 car-loads of freight.